Equity and Social Considerations related to Climate Change

WMO UNEP

Papers presented at the IPCC Working Group III Workshop on Equity and Social Considerations Related to Climate Change
Nairobi, Kenya, 18–22 July 1994

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Opening Session

Chair : James P. Bruce

Preface

This was the fourth and last in a series of Workshops sponsored by the Third Working Group of IPCC. The purposes were:

1. To provide a broad base of input to the writing of the draft chapters for IPCC's Second Assessment Report, and
2. To provide an opportunity for policy advisors in several regions of the world to gain a better understanding of the scope and nature of Working Group III's assignment.

Working Group III has been charged with addressing the so-called cross-cutting issues related to greenhouse gases and climate change. This means primarily those issues of a regional or global social and economic nature, and evaluation of policy options. Many of these aspects of climate science, especially in the social and economic sciences, are new departures for IPCC. They have required assembling teams of writers from the social sciences who have not previously been involved in IPCC assessments. These subjects are also the ones in which local and regional knowledge are very important, but often not reflected in the published literature which the IPCC is traditionally required to assess. Thus, the Bureau of WG III has considered these workshops, in Asia, South America, Europe (involving Newly Independent States) and now in Africa, to be a very important part of our assessment process.

Each workshop has had a topical component, addressing one of the important themes of chapters of the Second Assessment Report, and a regional component to provide for better two-way communication on social and economic aspects of the climate issue. This one, in Nairobi, in addition to the African Regional component, addressed Equity and Social Considerations.

Readers of this volume will find a wealth of thoughtful and provocative papers on equity between generations, between countries and regions, and within countries. The relationships between climate variability and change, especially droughts, and social instability in Africa are explored. Implications of inter-generational equity, for interest rates that should be used in economic analysis of climate change, are discussed. Presentations include theoretical analysis as well as practical, down-to-earth concerns for equity and social effects.

JAMES BRUCE
Co-Chair, IPCC Working Group III

Opening Address

Equity and Social Considerations Related to Climate Change

HOESUNG LEE
Co-Chair, WG III, IPCC

Equity and socio-economic considerations are critical issues in developing appropriate response options to climate change. The issues become more complicated and confused when equity considerations require global perspectives. I believe this workshop will contribute greatly to improving the understanding of the relevant issues necessary among countries with different levels of industrialisation.

It is highly significant that we start with a regional session for our workshop. Countries in Africa are endeavouring to expedite the development process, amid the growing concern on potential adverse impact of climate change and the desire for sustainable growth. How this region incorporates into its policy configuration conflicting issues arising from sustainability, equity, and economic development, gives an important signal to other parts of the world.

This Nairobi workshop is one of a series organised for Working Group III, of which main concern is the socio-economics of climate change. Among the issues to be addressed in this workshop are the interrelation among science, society, and values concerning climate change. Also the inter- as well as intra-country equity issues affecting the equitable distribution of damages and mitigation costs will be discussed. It is my understanding that the transfer of technology will play a key role in ensuring the fair share of mitigation costs. Overall, the concept of "common but differentiated responsibility" stipulated in the Climate Convention needs our full attention in the context of inter-country equity.

Climate policy also raises a number of questions on equity considerations across generations. Although future generations are not able to participate in the current policy-making process, the policies taken today will affect their well-being in the future. Thus our discussion needs to address not only the responsibility of the current generation to correct problems arising from the actions of the past generations, but also the responsibility of the current generation with regard to the future. This is easier said than done. This is another reason why we need this workshop.

I would like to take this occasion to express my sincere gratitude to the speakers, moderators, discussants, and all other participants of this workshop who will advance our knowledge in many ways. As always has been in our previous workshops, we will benefit greatly from your participation. I am certain that this workshop will be a major contribution to the preparation of the IPCC Second Assessment Report.

Also, I would like to express my deepest appreciation for the support from the Government of Kenya, Professor Odingo, the Local Organising Committee, and the United Nations Environment Programme.

Speech by the Minister for Environment and Natural Resources on the Occasion of the Opening of the Intergovernmental Panel on Climate Change (IPCC) "Workshop on Equity and Social Considerations"

Nairobi, 18 July 1994

Mister Chairman, United Nations Under-Secretary General and the Executive Director of UNEP, Ms Elizabeth Dowdeswell, distinguished guests, Workshop participants, Ladies and Gentlemen.

It is a great pleasure for me to be here this morning to welcome you all to Kenya, and to open this important workshop being held on behalf of the Working Group III of the Intergovernmental Panel on Climate Change (IPCC).

As the Ministry responsible for environmental and natural resources issues in the Kenya Government, we have been very much involved with the spate of environmentally related conventions that have marked the concerns and activities of the United Nations system and the International community over the last few years, and in particular since 1986. First it was the Vienna Convention for the Protection of the Ozone Layer, which was quickly followed by the Montreal Protocol on Substances that Deplete the Ozone Layer. Even at that earlier time, Kenya has always been actively involved in the various discussions and negotiations leading to the establishment of this Convention. I am happy to mention the fact that Kenya was one of the 155 countries which signed the Biodiversity and Climate Conventions in Rio as well as the Agenda 21 on Sustainable Development. We are also closely involved in the just concluded Convention on Desertification.

Kenya has been very closely associated with these Conventions, and has kept a keen interest in seeing that each one of them brings the environmental benefits to human societies such as were intended. I should also announce that the Kenya Government is actively pursuing the preparation of instruments for the ratification of the Framework Convention on Climate Change (FCCC), in preparation for the First Meeting of the Conference of the Parties (COP) which will be held in Berlin in Germany in March 1995.

Mister Chairman, the Kenya Government is fully aware of the fact that human activities are responsible for the threatened climate change. Kenya together with other 155 nations of the world, resolved in Rio when it signed the Framework Convention on Climate Change, to do something positive in cooperation with other nations, to prevent global warming by helping to reduce the emission of Greenhouse Gases (GHGs).

A workshop such as the present one presents us with an opportunity for meaningful synergistic exchange of views between experts as well as policy makers from various parts of the world. To achieve a good measure of understanding, there should be a free and informed discussion of all the issues including those that are of special concern to the African Region as I see in your programme.

The topic of the present workshop, namely "Equity and Social Considerations of Climate Change" is not an easy one, and speaking on behalf of the developing world, we are keen that it receives proper attention and full coverage from as many angles as possible. Equity has been at the heart of every international debate for the last 20 years. For example, developing countries have often underlined the need for a more equitable sharing of the earth's resources, poverty alleviation and the need for debt relief, and more distributive justice.

Mister Chairman, since today's meeting is being held in the context of IPCC activities, I would like to say something briefly about the Convention and how we in the developing world see it. This Convention like its other sisters sprang from the increasing concern about environmental matters, and the damage that human populations are doing to the global environment. There was inevitably the serious concern by the nations of the world for the need to enact effective environmental legislation, to uphold environmental standards, and to see environmental issues as being closely intertwined with economic development. There was an early realisation during the negotiation process and in Rio that "all nations may be equal, but some are more equal than others". The issue of climate change truly highlighted this dictum, and, fortunately these differences were reflected in the Convention which we have been privileged to be associated with as one of the 155 signatories at Rio. The FCCC has before it a truly heavy task, and it will take a lot of goodwill by the international community to see it through. Its main objective is stated as follows:

> "Stabilisation of Greenhouse Gas concentrations in the atmosphere at a level which would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner".

The socio-economic context of climate change is very evident, and the IPCC should be congratulated for establishing Working Group III to concentrate on this aspect of climate change. Mister Chairman, we are aware of the hard work being carried out by the IPCC process, and today's meeting is evidence of what is being done through cooperation among various scientific groups, including the social scientists to better understand the complexities of impacts and adaptations that may be required in the event of climate change, and in this case, in the event of global warming. The topic of your meeting today and for the rest of the week is of great interest to the Kenya Government. The issues of "Equity and Social Considerations" are at the heart of relationships between states, and especially for those of us who happen to live in the developing countries. In the negotiations leading up to the Convention (FCCC) the concept of equal but differentiated responsibilities between the developed and developing nations was not only accepted, but it was also enshrined in the Convention. We share your concerns about the complexities evident in attempting to apply scientific ideas to societies that are each endowed with their own differing values. We too are keen to obtain policy advice on issues such as intergenerational equity, on equity issues between the developed and developing nations, equity issues at home such as here for our own people in Kenya; relationship in Africa between our own country and our neighbours, including all those other states in the continent of Africa; how international agreements affect each of our countries, and many relevant issues which are of great concern to us such as debt and debt servicing, and international trade.

Mister Chairman, Climate Change will spare no one. We in Kenya are always faced with crippling droughts such as the one we have just emerged from, which seriously impact on our economy every time it appears. A large part of our country is threatened with desertification, and as our population continues to expand, the availability of good agricultural land becomes increasingly worrisome, since a move to the drier margins always carries with it the dangers of land degradation and desertification. We are not free from problems caused by drought such as those concerning environmental refugees. As a matter of fact this very moment there are close to half a million refugees from the problems in our neighbouring countries of Somalia and Sudan. Not all of them have run away because of drought, but it is clear that the devastation of drought and famine lead to political instability in many parts of Africa.

Mister Chairman, Kenya relies heavily on tourism as a source of foreign exchange. Whereas the game reserves and national parks in the interior of the country, as well as the beautiful scenery in the highlands, may be the first line of attraction, we also rely heavily on our pristine beaches along our coastline for resorts. In the event of global warming accompanied by sea level rise, such as we read from the reports of the IPCC, our beaches may be threatened, and our coastal tourism may be disrupted. We thus want to take a very keen interest about what the IPCC is saying about these things, and especially how a country like Kenya can weather the economic adversities in future. I can see from your programme of work that these are some of the issues that IPCC is trying to address, and we would like to give you every encouragement because we know that as governments, we stand to benefit from the intense interdisciplinary discussions that you are holding in this and other fora.

Mister Chairman, before I conclude, I would like to welcome all the participants to Kenya, and to hope that during and after your deliberations you will find time to sample some Kenyan hospitality, and to visit some of our beautiful sights before you return to your homes. Kenya as you are well aware is proud to host the United Nations Environment Programme, and Habitat, as well as many other agencies in the United Nations ~~System~~ which have now joined this United Nations Village at Gigiri in Nairobi. We will do everything to make you feel welcome. Once again, please enjoy your stay while in Kenya.

Mister Chairman, it is now my pleasure to declare your Workshop open, and to wish you all Godspeed in your deliberations.

Thank you all.

African Regional Workshop

Chair : Richard S. Odingo
and Mark Mwandosya

Rapporteur: Grace Akumu

Introduction to Working Group III

JAMES P. BRUCE
Co-Chair, WG III, IPCC

African Regional Seminar Session

As the Opening Session made clear, the charge to WG III is a new and challenging one. The Working Group has been most fortunate in being able to assemble a remarkable lead authors team of leading economic and social scientists, leavened by some natural scientists and a few political and policy specialists. As for all IPCC Groups, we are charged with assessing available literature on social and economic aspects of climate change. This is one of IPCC WG III Regional Sessions to brief you on WG III activities and learn more about African concerns on economic and social aspects of climate change. We plan to leave you lots of opportunity for questions about WG III's activities.

The main outline of those issues which countries wish to have addressed in our report emerged from the country views at the plenary session of the Working Group, at its first session in Montreal a little over a year ago. While equity issues were not given many words in the Montreal outline, it was clear that delegates considered them very important. They wish to have as much objective information as can be assembled from published material to help make policy and political level discussions as well informed as possible. Thus when dividing the work of preparing draft reports, a strong Working Team was established to undertake the drafting of this chapter on Equity and Social Considerations of the IPCC's Second Assessment Report. Most members of the Working Team are here, and are on the last day's panel. Unfortunately, Harold Jacobson, Convening Lead Author, could not be with us for health reasons.

There are two major deadlines to which we are working:

1. Special Report—to be ready for review and approval at IPCC Plenary here in Nairobi in November so as to be available for First Conference of the Parties to the Framework Convention on Climate Change in March 1995.

   There will be six chapters:

   1–5 up-dating science of radiative forces of climate by greenhouse gases and other factors by WG I,

   6th reviewing global and regional emission scenarios, by WG III for approval at WG III Plenary 27–28 September, Geneva.

   Drafts for these chapters are now out for review by peer review specialists and governments.

2. Full Assessment Report—10 chapters from WG III. Early drafts to be distributed for first peer review in autumn of this year. The Report will be reviewed and approved by Working Group III Plenary in June 1995 in Geneva.

We are anxious to have as much input as possible from countries of this region and especially to uncover publications and literature which may not be otherwise available to the lead authors. We urge your active help and support.

Now Dr Erik Haites, a well known economist in the field of climate change and energy policy, who is the very effective head of the WG III Technical Support Unit and largely instrumental in mobilising members of the economics community to help prepare reports, will outline the themes of the 10 chapters now in preparation.

Capacités Institutionelles Africaines pour Repondre aux Dispositions de la Convention Cadre Concernant le Changement Climatique

YOUBA SOKONA
ENDA-TM
54 Rue Carnot, BP 3370, Dakar, Senegal

Abstrait—La creation et/ou le renforcement des capacités africaines d'analyse, de formulation de politiques et de prise de décisions stratégiques les mieux adaptées est une condition primordiale à toute perspective d'internalisation des problèmes environnementaux globaux aux préoccupations des pays africains.

Introduction

L'entrée en vigueur de la Convention Cadre sur le changement Climatique en mars dernier, oblige désormais tous les pays à entreprendre des actions contribuant à la réduction des effets délétères des émissions anthropiques de gaz à effet de serre. Par ailleurs, il ne fait plus de doute que toute perspective de réduction ou de stabilisation de ces gaz n'est envisageable que dans une approche globale. Les nations les plus nanties, comme celles les moins favorisées, se trouvent confrontées à ce que l'on pourrait appeler un temps de l'urgence spécifique dont personne n'est en mesure de cernier la borne supérieure. En d'autres termes, ce phénomène pourrait engendrer des conséquences irréversibles ou impliquer des coûts de résolution si élevés qu'il n'est point sage d'attendre, avant de prendre à l'echelle collective des *mesures conservatoires*.

Poser tel quel, ce problème environnemental est par trop réduit à sa limitation des "effets directs" qui, pour la plupart des pays du Tiers Monde et surtout des pays africains, ne sont qu'un sous-ensemble d'une problématique beaucoup plus large dont un des points cruciaux a trait à leurs perspectives de développement.

Les pays du Tiers Monde et plus particulièrement ceux de l'Afrique sub-Saharienne confrontés à une crise endémique seraient peut être tentés d'y traiter les problèmes liés aux émissions anthropiques par prétérition. Si tel était le cas, on ne saurait leur en faire grief puisqu'ils sont acculés à un nombre de problèmes simultanés d'une ampleur peut être jusqu'alors inconnus sur la planète. Il n'est cependant pas exclu qu'une réflexion soutenue, et propre aux africains eux-mêmes, sur les problèmes environnementaux planétaires comme les émissions de gaz à effet de serre puissent enrichir leur capacité à résoudre leurs propres problèmes. A condition toutefois qu'ils aient un réel pouvoir de décision, une capacité interne d'organisation et d'action.

Les Axes Prioritaires ou Urgents de Préoccupations

Est-il encore besoin d'évoquer les priorités ou les urgences au plan économique, social et politique de chacune des nations africaines? De toute façon, quelque soient les axes identifiés, la question lancinante qui demeure est: que faire, et comment, pour transformer la vie quotidienne du plus grand nombre et pour améliorer, à la fois, le niveau de vie et l'environnement des plus démunis et des exclus? En effet, la persistance de la pauvreté et l'accentuation des disparités socios-patiales mettent beaucoup de pays africains dans une situation sociale, économique et politique de plus en plus explosive. Dans la perspective de recherche de solutions à cette donnée fondamentale, les pays africains, notamment dans le processus de la préparation de la conférence de Rio, au cours de certaines concertations ont dégagé et affiné des axes prioritaires de leurs préoccupations communes, à savoir:

- la sécurité alimentaire;
- la sécurité énergétique;
- la durabilité de la croissance économique et de l'emploi;
- la sécurité et la stabilité des ressources financières;
- l'amélioration de la qualité de la vie et de l'habitat.

Ces préoccupations se retrouvent dans la plupart des rapports nationaux établis pour "le sommet de la terre". Chacun de ces domaines d'intérêt majeur agit directement ou indirectement sur les autres et en même temps subit leurs conséquences. Par ailleurs, à des degrés divers, ils sont tous causes et conséquences des problèmes environnementaux du continent.

Sans négliger l'importance d'aucun des axes retenus, nous nous limiterons ici à l'examen des préoccupations alimentaire et énergétique en raison de l'urgence de la première et du rôle central de la seconde.

Securité Alimentaire

Le problème le plus vital en Afrique est sans nulle doute, le besoin d'arrêter le déclin des rendements agricoles et d'augmenter la sécurité alimentaire en produisant plus de nourriture et en améliorant le stockage et la distribution des produits agricoles. Jusqu'ici, l'augmentation relative de la production agricole africaine a été rendu possible non pas par un gain de productivité mais par l'extension des superficies cultivées. En effet, les défrichements agricoles, principales causes du déboisement et d'érosion des sols, ont été rendus nécessaires pour satisfaire les besoins alimentaires d'une population en forte croissance. Les méthodes basées sur le système de longues jachères et qui permettaient à l'homme d'evoluer en parfaite harmonie avec la nature a été rompu. La réduction des temps de jachère a de ce fait, empêché la régénération correcte des écosystèmes.

Les pratiques agricoles dominantes (système extensif et/ou itinérant) constituent donc des causes fondamentales de dégradation des sols et du recul inquiétant des formations forestières primaires. Ainsi, les défrichements agricoles atteignent aujourd'hui 250,000 ha/an, en Côte d'Ivoire, et entre 60,000 et 100,000 ha/an dans chacun des pays sahéliens du Burkina Faso, Mali et Sénégal. Par exemple le rythme des défrichements de la Côte d'Ivoire avait atteint, au cours des années 70 et le début des années 80, près de 500,000 ha par an.

Le faible pouvoir d'achat des paysans ne leur permet pas l'acquisition de facteurs de production, nécessaires à l'intensification de l'agriculture. Par ailleurs, les capacités financières limités des Etats sont généralement sans commune mesure, avec les efforts qu'il faut déployer pour rétablir les équilibres écologiques tout en évoluant vers des systèmes rationnels de production agricole.

Sécurité Énergétique

Plus que partout ailleurs dans le monde, l'énergie est un des problèmes majeurs sous-jacents du continent africain. Dans les prochaines décennies, l'Afrique doit nécessairement augmenter sa consommation énergétique si l'on veut sortir le continent de son état de sous-développement et répondre aux exigences sociales de meilleures conditions de vie. Le problème énergétique est posé, dans les pays africains, en des termes particulièrement graves, car bien que le continent soit généralement considéré riche en ressources énergétiques, les quantités mises à la disposition des populations restent particulièrement faibles: le rapport entre les consommations d'elecricité des pays les plus riches et l'Afrique est supérieur à 150 et le taux d'électrification des villages reste, en Afrique sahélienne, inférieur à 5%.

Certes, les situations spécifiques des pays du continent sont diversifiées, mais certaines sous-régions possèdent des caractéristiques relativement proches. Par exemple, pour les pays sahéliens, on peut schématiser la situation énergétique actuelle par, d'un côté, une forte dépendance vis-à-vis des approvisionnements en hydrocarbures—ce qui perdure et amplifie les déséquilibres des balances de paiement et la dette—de l'autre côté, un prélèvement massif sur le couvert végétal pour des besoins énergétiques—ce qui accroît le processus de désertification (plus de 2,5 millions d'hectares sont défrichés chaque année sur le Continent). On est au cœur de la problématique énergie-environnement.

Perception des Problèmes Environnementaux

Toutes les analyses des conditions économiques et sociales de l'Afrique, permettent de mettre en évidence la crise profonde qui secoue le continent de manière permanente depuis près de deux décennies. Cette situation s'est aggravée par la difficulté croissante de mobilisation de ressources financières pour les programmes sociaux. La plupart des pays ont été amené à s'engager dans des programmes de stabilisation économique ou d'ajustement structurel. Aussi, la gestion du court terme et du quotidien devient la seule préoccupation à laquelle on s'attelle réellement. C'est ainsi que de nombreux responsables africains pensent et affirment qu'ils ne sont pas concernés par les préoccupations liées aux émissions de gaz à effet de serre. Cette attitude trouve son origine également dans le fait que la plupart des problèmes environnementaux qui affectent actuellement le continent africain, ont des effets directs et locaux sur les populations. Il s'agit donc principalement d'assurer la survie des populations en arrêtant la dégradation des écosystèmes où se sont notamment développés des systèmes d'exploitation agricoles, forestiers ou d'élevage. On est essentiellement préoccupé par la préservation des sols, le reboisement, la lutte contre les feux de brousse, c'est à dire toutes mesures nécessaires à la restauration immédiate des milieux d'exploitation qui répondent plus à la demande. Dés lors, il s'avère difficile d'allier ces objectifs à une protection des milieux pour le long terme. En d'autres termes, avant de penser à assurer la survie des générations futures, il faut fournir à la population actuelle les moyens de se nourrir et de vivre. C'est ainsi que dans le cadre d'une déclaration commune, les Etats africains ont réaffirmé leur droit légitime à exploiter leurs ressources naturelles à des fins de développement et veillent à ce que les mesures de protection de l'environnement ne compromettent pas le processus de développement. Même si l'on est conscient de la dégradation des écosystèmes, le sentiment fort qui domine est que la protection des ressources naturelles ne doit pas constituer une condition préalable à imposer par les institutions de financement du développement et les bailleurs de fonds pour le développement économique des pays africains.

Contradiction et Dilemme, Faut-il se Résigner?

Personne ne conteste le rôle majeur qu'à jouer l'énergie notamment le pétrole dans la croissance et le développement des pays du Nord. En même temps et à l'échelle de la planète, elle est reconnue, depuis son exploitation jusqu'à sa consommation, comme une des sources prépondérantes de dégradation de l'environnement.

Dans les pays africains, et plus particulièrement dans les zones rurales, la faible consommation énergétique est tout à la fois "cause et conséquence" des difficultés de développement et, en même temps, participe à la détérioration de l'environnement naturel (comme la déforestation). En effet, les prélèvement incontrôlés de la biomasse participe à l'érosion des sols, aux inondations et peut aller jusqu'à compromettre les résultats de certaines actions de développement.

Dans un tel contexte, on ne peut s'étonner que les problèmes de l'environnement soient perçus, entre le Nord et le Sud, à des niveaux différents et avec des sensibilités économiques et culturelles dissemblables même si l'on est conscient qu'ils constituent une contrainte incontournable.

Que la "contribution" des pays africains à l'augmentation des émissions de gaz à effet de serre soit faible paraît une évidence. Que des dispositions communes soient retenues pour le juguler ne peut s'admettre qu'à partir du moment où celles-ci ne constituent pas un frein au développement. En effet, grâce à la maîtrise de nouvelles technologies, des instruments d'analyse et de prospective, les pays du Nord ont une faculté développée d'adaptation à de nouvelles contraintes, mais il n'en est hélas pas de même pour les pays du tiers monde et plus singulièrement ceux d'Afrique. Ces derniers utilisent des techniques de production souvent dépassées (electricté par exemple) et, pour les biens de consommation, ils ne constituent le plus souvent que des marchés résiduels (électroménager) voire d'occasion (automobile).

La production et la consommation s'inscrivent d'emblee dans un contexte de très faible rationalité sur le plan énergétique. On est d'ailleurs en droit de s'étonner que certains proposent un monde "vivable" dont la dominante serait la production et la consommation de nouveaux produits à haute densité technologique et à faible consommation énergétique, ce qui en exclut *ipso facto* les pays qui ne peuvent qu'accéder a des produits arrivés en phase de saturation (cf. l'évolution des prix au cours du cycle de vie du produit). En bref, les pays les moins avancés se trouve une fois de plus relégués à adopter les techniques de production et les biens de consommation les moins performants sur le plan énergétique, etc...

Si on ajoute le poids de la variable démographique (50% de la population est âgée de moins de 17 ans dans certaines régions et pour le même pourcentage est concentrée dans les villes), on perçoit mal comment des pays qui ont déjà bien du mal à entretenir leur parc d'équipement existant, pourront faire face à une demande qui devrait croître de façon quasi-exponentielle, même si l'utilisation de technologie peu efficiente continue de priver de sa consommation bon nombre de populations, les tarifs pratiqués étant très sélectifs.

Les Stratégies de Réduction des Émissions de Gaz à Effet de Serre: Approche Economiste? Ou Approche Plutôt Pragmatique et Volontariste?

Aujourd'hui, sur le plan technique, de nombreuses options existent quant à la réduction des émissions délétères de gaz à effet de serre. Chacune d'elles exige cependant une autre façon de produire, de consommer ou tout simplement de vivre.

Dans le secteur de l'énergie qui se trouve être le plus important contributeur de ces émissions, les mesures de réduction vont de l'amélioration de l'efficacité dans toute la filière (de la production à l'usage final) aux substitutions des combustibles fossiles par les combustibles renouvelables non émettrices. Dans les domaines de l'agriculture, de la forêt ou du cadre de vie diverses options sont envisageables dans chaque cas de figure.

Chacune des options qui pourraient être envisagées a un coût plus ou moins important. Aussi, sa mise en œuvre sera fonction de critères économiques qui semblent être focalisés sur la recherche d'un meilleur rapport coût-efficacité. La globalité et la nature particulière du phénomène de l'effet de serre ne rend pas aisé comme nous allons le voir, l'utilisation de tel instrument d'aide à la décision.

Des travaux d'orientations méthodologiques se dessinent globalement deux approches avec une première basée sur le coût marginal et une seconde axée sur la nécessité d'infléchir un scénario de référence à partir d'un certain volontarisme.

Les Références au Calcul "La Marge" où "Rien ne Change Parceque Tout Devrait Changer"

Les principes directeurs pour les choix d'options relèvent de la théorie néoclassique et du calcul économique sous-jacent et comme dans de nombreux autres domaines, montrent une fois encore leur inapplicabilité, en particulier la recherche de l'optimum global par le calcul à la marge.

L'approche qui semble dominer tout au moins dans le cadre du FEM consiste à optimiser le rapport coût-efficacité de ses interventions. L'enveloppe du FEM étant fixée, il s'agit en fait de maximiser les réductions d'émissions. D'oú les "costings studies" qui doivent fournir un cadre de référence précis en vue de la définition d'une stratégie d'investissement.

Mais comme dans le domaine social (débat des années soixante dix) l'utilisation de cet outil de calcul butte sur le mode de prise en compte du bénéfice global (choix d'un taux d'actualisation ou d'un prix de référence). Sa quantification ou l'utilisation d'un prix de référence aux émissions cachent derrière une pseudo neutralité théorique (réduction des coûts futurs, gain de temps, amélioration de l'information, valeur d'option) la volonté de faire croire que la théorie économique peut dans tous les domaines apporter des réponses objectives dans des domaines où les définitions sont, par essence, controversée et non objectives. On retrouve ainsi dans le domaine du risque climatique les mêmes débats qui ont animé les Sciences Sociales, à savoir que, derrière des propositions couvertes du voile de l'objectivité économique, ce sont autant de conceptions et de vues normatives qui s'expriment.

Tout approche marginaliste s'inscrit à la marge du développement: Il faut obtenir le maximum de réductions pour un investissement minimum et ce, indépendamment du contexte et quelque soit les implications stratégiques. On se situe dans le court-moyen terme quelque soit les implications sur le modèle de développement.

Le Pragmatisme et le Volontarisme de l'Approche du STAP

A l'inverse le STAP a préconisé une approche volontariste et pragmatique qui, opposée à la précédente, constitue le véritable enjeu pour les pays africains.

En se dégageant des approches économistes, les membres du STAP, ont élaboré des critères d'éligibilitée et de priorités pour sélectionner les projets. Ceux-çi ont l'avantage de procéder d'une analyse globale qui intègre aussi bien des facteurs géographiques, d'exigence de reproductibilité, de pérennisation, etc... C'est à dire de résoudre un problème non strictement économique par une méthode qui tienne compte de la globalité des facteurs quantitatifs et qualitatifs mais surtout non strictement économiques.

Regroupés sous forme de matrice d'objectifs (intervention/étapes ou approche),ces critères permettaient d'opter pour un portefeuille équilibre de projet (équilibre thématique et géographique). Cette approche résolument normative est éminemment qualitative (expérience et "dire" d'experts). On peut d'ailleurs s'étonner (mais on ne le fera pas) des critiques formulées par la Banque Mondiale qui préfère une approche économique quantitative et basée sur le calcul économique au moment où toutes les anticipations et prévisions économiques sont de plus en plus basées sur des méthodes qualitatives (le quantitatif n'etant à ce niveau qu'un des outils d'aide à la décision).

Un point est acquis, au delà de la phase pilote, les ressources disponibles du FEM ne sont pas à la hauteur des exigences financières, il ne peut donc y avoir de politique d'investissement systématisée, mais promotion de technologies ou d'approches innovatrices faisant figure de précédent (apprentissage et approche dynamique).

Or le retour à la notion de coût-efficacité des investissements comme critère unique d'éligibilité (d'où le choix de technologies éprouvées) ramènerait à une logique marginaliste essentiellement axée sur le gain de temps. C'est pourquoi, l'alternative reste de s'inscrire dans une approche volontariste axée sur le concept de prédiffusion et, pour les priorités de financement, basée sur l'approche normative définie par le STAP dans la phase pilote. Dans cette perspective, il est fondamental que se développent en Afrique le plus rapidement possible des compétences pour faire émerger des actions consistantes et systématiques.

Une Nouvelle Opportunité pour les Pays Africains

L'Afrique comme la plupart des régions en développement serait particulièrement vulnérable aux impacts potentiels de changements climatiques. Ceux-ci pourraient accentuer le phénomène de désertification et perturber le système de production agricole qui accuse déjà un déficit chronique. Parmi les autres impacts négatifs possibles figure l'inondation des zones du littoral qui présente déjà des signes d'érosion avancée notamment en Afrique de l'Ouest et de l'Est.

Malgré sa part encore faible des émissions anthropiques de gaz à effet de serre, l'Afrique peut offrir un potentiel intéressant de réduction ou de stabilisation de ces gaz, voire d'augmentation de puits de séquestration. Le défi majeur consiste à identifier les politiques et les programmes qui favoriseront la réalisation des priorités actuelles en matière d'environnement et de développement à l'échelle locale, nationale et régionale, tout en contribuant à réduire les émissions de gaz à effet de serre ou à accroître les puits d'élimination de ces gaz. Des possibilités existent dans chacun des axes prioritaires identifiés par les pays africains.

Dans la séquence alimentation, pour ne citer que ce seul exemple, la généralisation ou l'introduction de méthodes, pratiquées avec succés, qui permettent d'intensifier la production agricole tout en réduisant les intrants (et par conséquent les coûts) c'est à dire les technique de l'agroforesterie et de la culture organique, peuvent à la fois contribuer la situation alimentaire tout en réduisant les émissions de gaz à effet de serre. En effet, dans les systèmes agroforestiers, des arbres sont utilisés comme fixateurs d'azote, pour remonter les éléments nutritifs des horizons plus profonds et pour éviter l'érosion. Ils fournissent aussi du bois de feu, du fourrage pour les animaux et des revenus variés. La culture organique augmente la fertilité du sol par l'adjonction de matières organiques et réduit les dégâts des insectes et maladies grâce à la culture en couloir et autres technologies intégrées de lutte contre les nuisibles.

La culture basée sur l'agroforesterie et les engrais organiques augmentent la production alimentaire. Elle réduit les intrants coûteux et rend l'agriculture plus flexible et capable d'adaptation. Elle restaure et maintient les niveaux de carbone dans le sol. Par conséquent, si de telles méthodes sont largement pratiquées, elles peuvent changer les sols africains de sources en puits de carbone.

Tout ce qui précède monte bien qu'il y a là une nouvelle opportunité pour si l'on peut dire "revisiter" les programmes de développement en les conciliant avec la nécessité de faire face aux problèmes environnementaux globaux et notamment le changement climatique.

La Nécessité de Création et/ou de Renforcement des Capacités

De toute évidence, l'enjeu central de toute stratégie de réduction ou de stabilisation des émissions de gaz à effet de serre dans les pays en développement est relatif aux questions financières. Ces questions soulèvent à la fois les problèmes d'équite et d'éfficacité qui sont le plus souvent antinomiques suivant que l'on aborde le sujet des émissions de gaz à effet de serre d'un point de vue du Sud.

Le problème de l'équité, au delà des autres considérations, s'analyse en fonction de la prise en compte des préoccupations locales et surtout des objectifs de développement comme cela a été à maint reprise souligné. Dans un certain nombre de cas il est possible de concilier cette exigence avec les préoccupations globales et dans d'autres plus difficilement. Dans tous les cas, les pays en développement ont moins de marge de manaeuvre pour discuter en position moins inégale du partage de la contrainte environnementale globale.

Comme en témoignent de nombreux travaux, notamment ceux relatifs au concept des couts incrémentaux, la maximisation de l'utilité des ressources disponibles permet d'établir un ordre de priorité des options de réduction des émissions de gaz à effet de serre. La raréfaction des ressources financières pour les programmes de développement constraint de plus en plus de pays africains—pour autant qu'ils aient la possibilité d'accès à un financement—à établir également un ordre de priorité des préoccupations nationales. Dés lors, des conflits d'intérêt sont manifestes dans un contexte où les pays africains sont particulièrement moins outillés pour faire de la contrainte environnementale un facteur de développement. Aussi, que faire pour renverser cette situation?

La première urgence est sans nul doute, celle concernant la création et/ou le renforcement des capacités locales d'analyse, de formulation de politiques et de prise de décisions stratégiques les mieux adaptées au contexte africain. En effet, la participation africaine dans le processus de négociation de la convention sur le climat a été relativement l'une des plus faibles que ce soit au niveau gouvernemental, non gouvernemental ou que ce soit au niveau de la communauté scientifique.

La multiplicité des questions relatives au changement climatique comme le temps alloué aux négociations, le manque et/ou la faiblesse de structures institutionnelles adéquates et de compétences, n'ont pas toujours favorisé le développement d'une stratégie africaine. Aussi, il apparaît une faiblesse sinon une absence de la prise en compte des particularités africaines lors de l'elaboration des instruments et outils développés comme des mécanismes mises en place (l'Afrique est le continent qui a jusqu'ici le moins bénéficié du FEM).

Malgré cet handicap et pour mieux se préparer pour la mise en œuvre de la convention, quelques actions significatives ont été engagés notamment par des ONGs dans les domaines de la recherche, de la formation, de l'information, de la sensibilisation, de la communication et de l'assistance technique à des institutions gouvernementales. Ainsi se profile l'émergence de pôles d'excellence qui pourraient jouer un rôle d'animation.

Conclusion et Recommandations

L'entrée en vigueur de la convention comme cela a été déjà évoqué, appelle désormais à engager des actions de diverses natures en les inscrivant dans le long terme. Aussi pour une participation efficiente africaine, il est prioritaire de tirer les leçons des récentes expériences et de définir une politique de renforcement des compétences africaines aussi bien au niveau des ressources humaines comme celui des institutions. Une telle politique pourrait s'articuler notamment autour des points suivants:

- Identification d'institutions (critères de compétence) pouvant jouer un rôle d'animation dans le domaine du changement climatique et identification des besoins de ces institutions;
- Définition et négociation d'un mandat pour ces institutions dans le cadre des programmes de coopération bilatérale ou de coopération multilatérale;
- Identification au niveau national d'une institution à compétence pluridisciplinaire (critères bien définis) comme centre national d'excellence;
- Identification des besoins de l'institution choisie et élaboration d'un mandat dans le cadre national en synergie avec les centres régionaux.

Strategies for Integrating IPCC's Work into National Climate Programmes

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Introduction

This short paper is intended for the African Regional Session of the IPCC's Workshop on Equity and Social Considerations Related to Climate Change. The comments made will therefore be directed at the African scene with ideas being borrowed from other regions to find out what the African region needs to prepare itself to meet the challenges that are being presented to the nations of the world by climate change. When this paper was mooted, it was assumed that African countries have or should have climate programmes and that they should also not only be aware of the wonderful international scientific collaboration in climate research and comparison of results which have been made possible by the Intergovernmental Panel on Climate Change (IPCC), but that they should at the same time prepare themselves to participate as full partners in this great effort to make science relevant to human needs.

IPCC's Methodology

The Intergovernmental Panel on Climate Change was jointly established by UNEP and WMO to respond appropriately to human-induced global warming, by making careful reviews of the science of greenhouse gas warming and the likely impacts, mitigation and adaptation strategies that will be required to respond appropriately to the expected changes. The IPCC in their first assessment produced a majority scientific view that on the basis of existing evidence the greenhouse effect is bound to produce significant global warming by the middle of the next century (say by 2050) unless clear and rigorous policy interventions are put into operation to halt the trend. As all may be aware, the IPCC's work is being carried out by three Working Groups with clearly stated tasks which involve addressing the problem largely through the process of review of the available literature, and evidence of what research and modelling experiments have produced. It is essentially an "assessment process". Working Group I has the task of assessing the available scientific information on climate change and its terms of reference are as follows:

> "It should consider, *inter alia*, factors affecting climate change, including greenhouse gases responses to these current capabilities of modelling global and regional climate change and their predictability, past climate record and presently observed climate anomalies, and projections of future climate and sea level. The Working Group should identify the range of projections and their regional variations gaps and uncertainties. It should develop (in cooperation with OECD) methodologies for inventorying national net emissions of greenhouse gases by the countries of the world. A peer review process should be incorporated in the preparation of the reports."

Working Group II has the task of assessing "the environmental and socio-economic impacts of climate change, and analysing the technical means and socio-economic implications of integration and/or adaptation to climate change." The terms of reference of Working Group II are as follows:

> "Working Group II should review the environmental and socio-economic impacts of climate change, particularly on developing countries in an integrated manner. It should emphasise, *inter alia*, evaluation of impacts on regional/national scale of climate warming and sea level rise, the latter especially in the coastal and island areas, on agriculture, forestry and health, water resources and floods, droughts and desertification, energy and other sectors. The Working Group should include consideration of the impacts of a range of continuously changing climates. The Working Group should also consider, *inter alia*, forecasting and assessment of future emissions of greenhouse gases, impacts of changing technology, sources and sinks, adaptation to climate change, strategies to control or reduce emissions and other human activities that may have an impact on climate (e.g., deforestation, changing land-use and their social and economic implications) with

attention given to the special situation of developing countries."

A peer review process should be incorporated in the preparation of the reports of the Working Group.

Finally, when it was created, the new Working Group III was expected to deal with cross-cutting issues related to climate change. It was charged to review as follows:

(a) Technical assessment of the economics of climate change: In this respect the IPCC requested the Working Group to draft its terms of reference in regard to this task for approval by the IPCC.
(b) Emission scenarios: Initially it was thought possible that the Working Group could develop a set of credible, long-term scenarios describing future emissions of greenhouse gases to illustrate the range of plausible economic, demographic, and policy assumptions in order to assist Working Group I in the likely future changes of atmospheric composition and resulting climate change.

The Socio-Economics of Impacts, Adaptation and Mitigation of Climate Change

The work of Working Group III as recently re-instituted falls within this broad area intended to explore the cross-cutting issues which include the socio-economics of impacts, adaptation and mitigation of climate change. The mandate of the Working Group states that it should undertake:

> "Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short- and long-term and at the regional and global levels. The work plan should, *inter alia*, consider the following topics: top-down and bottom-up economic modelling; the evolution of technological change; methods for risk assessment; methods of the generic assessment of response instruments."

Our present workshop, for example, concentrates on only a small area of the wide field of cross-cutting issues which the Working Group must include in its assessment work. It concentrates on equity considerations including, *inter alia*:

> "Varying contributions between regions for past emissions, the 'free rider' problem, inter-regional and inter-generational equity and the question of the time lapse between the incurring of costs and the accruing of benefits."

One last area falling within the mandate of Working Group III involves the consideration of consistent scenarios, i.e., the Group "should consider a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections."

The development of existing scenarios was based upon certain assumptions, e.g.,

> "A discussion of the key assumptions concerning, *inter alia*, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain."

It will thus be seen that from the point of view of the African region there are three major areas of activity where cooperation with the IPCC process could be instituted, namely:

(1) Scientific and technical assessment of climate change—a review process to ensure a perfect understanding of how the atmosphere and related systems work and what is to be expected in the event of global warming which has been predicted with a certain degree of certainty. This work is being done by Working Group I of the IPCC.
(2) What to do in reviewing the various processes of impacts and adaptation, and the socio-economics of that process.
(3) The socio-economics of impacts, mitigation and adaptation which is a wide area which must be covered to establish the links of climate change with world economic processes in the various parts of the world.

Before commenting on attempts to integrate IPCC's work into national climate programmes, it is essential by way of summary to understand what the IPCC is all about. The following summary is intended to answer that question:

(1) That the IPCC should have a largely scientific role to enable it to work as a scientific and technical assessment body that remains removed from policy issues except in terms of stating the options available to the nations of the world.
(2) That the IPCC be truly international and intergovernmental and it is determined to remain an independent scientific and technical body.
(3) That in its endeavour to remain neutral and international it has taken into consideration the need to maximise the role and participation of developing countries particularly in its scientific work.

In all these efforts there was concern which has been well met, to take appropriate measures to further strengthen the scientific and technical character of the Panel in all its work within scientific and other bodies, and to provide for effective participation of scientific and technical experts from developing countries in its activities. An additional and equally useful recommendation in respect of IPCC's work came from the Executive Council of WMO in June 1992 which stated, *inter alia*, that the IPCC should:

> "Make recommendations on, and take appropriate measures to raise public awareness and facilitate education with respect to climate change including through the broad and timely dissemination of the Panel's work and its information exchange seminars effort".

Integrating IPCC Work into National Climate Programmes

Integrating IPCC's work involves a deliberate effort at the national level to address those concerns now being handled by Working Group I, namely sharpening our understanding of the science of climate change, followed by proper attention to the issues of climate impacts and adaptation as handled by Working Group II. This work naturally covers all national terrestrial ecosystems, the oceans and coastal zones, energy and industry, agriculture and forestry, hydrology and water resources, human settlements and socio-economic activities, including the impact of climate on human health, and many other similar areas likely to be affected by climate change. Then, there are the whole range of socio-economic issues which have hitherto been given only a cursory glance, and which now through the efforts of IPCC's Working Group III have been brought to the centre stage. In all these things, it must be noted that whereas IPCC's work calls for much inter-disciplinary activities, most countries in Africa have yet to organise themselves along similar lines to be able to put up comprehensive climate studies programmes such as are now being done by the IPCC. A limited amount of inter-disciplinary work is currently being carried out at some African universities and a few scattered research institutes, but for the moment at the national level, possibilities and scope for inter-disciplinary work is quite limited.

Facing up to the challenges of global warming calls for a new approach to viewing national climate programmes. In the industrialised countries the obvious response has been to create centres and institutes for global studies because it is only in such places that the required facilities are made available for the proper study of the multifaceted problems associated with climate change. Unfortunately, even the work on the cross-cutting socio-economic issues is only starting to be done.

In Africa, national climate programmes, if they can be called that still consist of a scatter of activities with many gaps. In particular the data collection systems are still very weak, except in a few countries. Analysis systems involving a certain amount of modelling are virtually non-existent. But there is now a real interest in the application of climate information to help solve national development problems. It is this kind of realisation that has led to the establishment of the regional centre known as African Centre for Meteorological Applications and Development (ACMAD). In turn this is already encouraging as well as coordinating national level activities involving the application of climate information on agriculture, forestry, range management and water resources, among others.

Some of the more coordinated and multi-disciplinary programmes in some countries in Africa include the work of ENDA-Tiers Monde in Senegal, Zimbabwe Energy Research Organisation (ZERO) in Zimbabwe, and the Kenya Energy Research Organisation (KENGO). But the initial aim of many of these organisations was fuelwood depletion rather than climate change (cf. Richard H. Hosier, *Zimbabwe: Industrial and Commercial Energy Use*. Stockholm, The Beijer Institute and Scandinavian Institute of African Studies, 1988; and C. Barnes, J. Ensminger and P. O'Keefe (Eds.) in *Wood, Energy and Households: Perspectives on Rural Kenya*. Stockholm, The Beijer Institute and Scandinavian Institute of African Studies, 1988).

The real issue is that to date many African countries do not have a national climate programme, and many of them will need technical assistance to start one before they can respond appropriately to the initiatives now being taken by the IPCC. A detailed look at many African countries reveals the fact that there is already adequate expertise to undertake such a task, and they are only waiting to be organised. As of now, there is a clear absence of an adequate institutional framework at the national level in many African countries for discussing climate issues. Even the recent moves to establish in many African countries, National Environmental Action Plans (NEAPs) with the assistance of the World Bank, have ignored the need for the establishment of National Climate Committees (NCCs) as well as a few viable inter-disciplinary national climate research centres to handle the important issues of climate and the closely related development sector, namely energy. It is not enough to tag climate work onto an ongoing national energy research programme because climate in itself is complex enough to demand its own centre.

Recently there have been new proposals by the UNDP to support universities in sub-Saharan Africa to enable them to undertake pilot studies of:

(a) Emissions of greenhouse gases (GHGs)
(b) Costing of abatement strategies
(c) Energy profiles
(d) Policy studies (in relation to climate)
(e) Networking of African country programmes.

In my view, many of these moves are premature, unless and until viable inter-disciplinary national climate programmes are put into place. The deliberate initiation of national climate coordinating committees in addition, will go a long way to provide the needed follow-up for national efforts to respond appropriately to the wealth of information that is now coming from the IPCC process, and will create a forum for a meaningful dialogue with, and critique of IPCC's work as currently carried out by the three Working Groups. The time is ripe for most African countries to start focusing on energy use and energy policies as likely to be affected by the new existence of the FCCC. Even though, except in the case of a few countries, their GHG emissions are minimal the need to characterise and understand the workings of their: (i) petroleum-based energy; (ii) biomass energy—especially wood fuel and its environmental implications; and (iii) general energy policies is crying out for attention. It is only then that they will be in a position to effectively contribute to the deliberations of IPCC and in turn to the negotiations that are soon to follow the first Conference of the Parties to FCCC which will start in Berlin in March 1995.

African Cooperation with the IPCC

There is no argument about African co-operation with the IPCC process. As a matter of fact, thanks to the IPCC Trust Fund assistance, African countries have been keen participants in all IPCC fora. However, further and more meaningful cooperation lies across three broad fronts, namely:

(i) Scientific and technical assessment of climate change, especially the African regional aspects. This is a review process to ensure a better understanding of the science of global warming. The African region is expected to help with the generation of the regional data required to be used in the various modelling efforts. The African region should also be more involved in the characterisation of the regional aspects which are required to bring greater clarity to the global modelling efforts.

(ii) What needs to be done in reviewing the various processes of climate change impacts, adaptation and mitigation? Already a fair number of African scholars are participating in the review process. They would be stronger if they were in turn supported by strong national climate research in each of the African countries.

Many of the issues covered by the IPCC Working Group II have a special relevance to the African region, and the work of the IPCC will be the more richer if there is a proper contribution from Africa. For example, Working Group II is expected to "emphasise the evaluation of impacts on regional and national scale of climate warming and sea level rise, the latter especially in the coastal and island areas, on agriculture, forestry and health, water resources, and floods, droughts and desertification, energy and other sectors". Virtually each of these issues mentioned can be enlightened by a more coordinated contribution from the African region because most of these problems being focused upon have excellent African examples to be included in the review text. Whether it be deforestation or desertification, the examples would be incomplete without mentioning African experiences. To this extent each African country should feel it is bound to benefit by closely being involved with the work of the IPCC. In the field of human activities, in the area of impacts of changing technology and in the study of the socio-economic impacts of changing land use or deforestation, African experience is bound to enlighten the rest of the globe. Even though there is not enough literature to be reviewed, the participation by African scholars will ensure that little known and even unpublished sources of information can be made available to the IPCC process to enrich the writing process.

(iii) The social aspects of climate change, involving studies of the socio-economics of impacts, adaptation and mitigation. Although some related work is already being done in this area, it is still too little and the African region is more of an observer. When it comes to discussions concerning poverty or equity the region should be in a position to contribute. Unfortunately climate-change related literature is still very scarce in Africa, especially in relation to those aspects which are of immediate concern to IPCC Working Group III. There are many areas of concern including the application of top-down and bottom-up economic modelling as applies to Africa, the evolution of technological change, methods of risk assessment, and methods of the generic assessment of response instruments.

Even though the African region is currently responsible for a very small amount of the global GHG emissions, individual countries will need to study and adopt appropriate policy instruments for responding to climate change. Such efforts can only succeed if indigenous institutions are put into place to assist the governments in deliberating on these matters. When it comes to issues of equity the African region is full of lessons which can be used to enrich the international debate purely at the professional, rather than political, level. Unless African countries quickly formulate meaningful climate response policies, many African countries will by default attempt to be "free riders" with all the inherent disadvantages. Nevertheless, with viable and well established national research groups on climate change, African countries will have available indigenous and expert advice on how to proceed. It is for this reason that emphasis is being laid on the need for national capacity as well as institutions to be initiated which then can be entrusted with assisting the policy people in the individual African countries as well as the African region as a whole.

The UNDP and other donor groups have already recognised the hiatus in the African region and are making efforts to assist individual African countries with more committed and scientific data collection, first steps at proper inventorying of GHG emissions, policy formulation to deal with mitigation and response issues, and a better understanding of the socio-economic implications of climate change. There are many other entry points to more meaningful work on climate related issues in each African country. For example, there is a crying need for work on energy efficiency programmes in each African country. To make all these more effective a viable coordinating mechanism will have to be established in each country using various vehicles, including the NEAPs provided the right emphasis is placed on working with the IPCC process.

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Equity, Communication and Climate Change: Access to Information and Communications Networks in Africa

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Abstract—In indigenous African societies, communication is essential to survival. Institutional frameworks have developed for the preservation and transmission of knowledge and these form integral and defining aspects of indigenous cultures. In the modern world, communication is also essential to survival.

Communicating in Africa

It is probably safe to say that every African in this room has experienced serious frustrations with communication. Scientists are often unable to access essential scientific papers and computer software. Policy-makers have limited access to international policy discussions and are often excluded from important meetings and debates. Key conferences are missed because of communications failures.

If intercontinental communication is difficult, communication among and within African countries is even worse. It is easier to access work done by Northern scientists than by fellow Africans. It is easier to discuss climate policy with Americans and Europeans than with fellow Africans. The results of studies done in Africa—usually commissioned by Northern institutions—disappear into Northern research archives or become part and parcel of Northern development initiatives, and are not available to Africans who would like to plan their own development. Policy documents that have already been negotiated by African governments are equally hard to come by.

Within countries, there is lack of communication among government ministries. Government officials, scientists, NGOs, Intergovernmental agencies, all may be doing work that could contribute to a climate response strategy. But they are not communicating with each other. Few countries have databases or bibliographies of climate research that has already been done in their countries. Duplication of effort is rampant.

Communication as an Equity Issue

The huge disparities between communications facilities in Africa and the industrialised world are obvious, particularly to those who have lived in both worlds. These disparities have been documented by several scholars, among them Jacques Habib Sy of the International Development Research Council, Nairobi Office ("Communications for Development, Democracy, National Independence and Economic Growth", in *Cultural Expression in the Global Village*, 1993, Malaysia: Southbound, pp. 58–79), Hamid Mowlana of the American University, Washington DC ("Information Hunger and Knowledge Affluence: How to Bridge the Gap", in *Development* 1993:3 Journal of SID, pp. 23–26) and Syed A. Rahim of the East-West Centre, Honolulu, Hawaii ("Communicative Action in Development", *Development* 1993:3 Journal of SID, pp. 36–40).

"The advanced industrial nations' ability to communicate globally and to process very large volumes of information at very high speed has increased dramatically over the past three decades. This technological progress has done little to reduce information gaps and inequalities among various countries and cultures and among population groups within many countries. A very large proportion of the world's population does not have the most basic access to telephone services, and the situation is not likely to change much by the end of this century." (Rahim, p. 37).

"Even the telephone, perhaps the most 'democratic' of media, demonstrates a wide gap between developed and developing countries. Not only are rates in developing countries higher for the same distance and time, but they are also

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higher between two points within developing countries than between developed and developing countries. Rates are higher for calls from a developing to a developed country than for calls in the opposite direction." (Mowlana, p. 23).

Scientists in the North have access to electronic mail, and database services are often provided free of charge by their institutions. Most Africans are lucky to have access to computers, let alone computer communications. Ninety percent of the world's computers are found in 15 of the most economically advanced countries, and 95 percent of all computers are in the developed world (Mowlana, p. 23).

Habib Sy summarises the situation in Africa as follows: "The new and irremediable fact about the African communications field is the absence of 'mass distribution' communication vehicles: telephones; telex; facsimile; televisions; and books. Even radio, which could be described as an obvious mass technology in the African context, remains, according to the most reliable statistics, an inadequate communication vehicle at the village and semi-urban level. Another complicating factor is that Black Africa has no self-financed indigenous database that is comparable from a strategic viewpoint to other structures of the same kind in the industrialized world."

"In fact", Habib continues—in a statement extremely relevant for African climate response planners—"Africa lacks even the baseline statistics that would confirm the relevance of its planning efforts. It must turn to the international financial institutions in Washington, Paris, Geneva, or London to prepare 'pseudo-plans' for development, unless it occasionally decides to rely simply on the science of 'development' wizards, i.e., 'cooperators', 'technical assistants', and other 'Africanists', ready to take up any doubtful cause concocted by hard pressed governments." (p. 59).

Africa is completely dependent on the industrialised nations and transnational corporations for its communications infrastructure and access to telecommunications facilities, such as satellites and radio frequencies. "With an estimated population of 600 million people... and the richest reservoir of natural resources in the world, Black Africa will have at best by the year 2000 four to six orbital slot locations out of a theoretical total number of 1800 orbital parking spaces... By the end of the century, therefore, the Black African countries' share of the geostationary arc may represent only 0.3% of this resource!" (Habib Sy, p. 71).

Africa's communications systems are dominated largely by the British and the French, with the United States and Japan also controlling a significant share (Habib Sy, p. 75). The drive for Northern control of African telecommunications continues under the World Bank's ideology of "privatisation". Jill Hills traces the development of the ideology of "privatisation" as a result of internal Bank needs and pressures from transnational corporations. The Bank has pressed for privatisation despite independent studies showing that private telecommunications facilities do not necessarily provide better services than state-owned companies. In some cases, services have deteriorated following privatisation (Jill Hills, "Economics as Ideology: The World Bank and Privatisation", unpublished).

The results of these communications inequities are clear for everyone to see. Amongst other things, specific to climate change, African interests are not being adequately defended in the international political, scientific and economic arenas. Information on Africa is not available for global models or decision-making processes. At the national levels, countries have not been able to develop the institutional and human resource capacity necessary to carry out basic research or formulate climate response strategies that are compatible with their own development priorities and sustainable development objectives.

Computer Communications

Computer communications networks have become an essential tool in the scientific community. Computer communications offers a relatively cheap, fast and easy way to send and receive information locally and internationally. While it is unlikely that the overall problems of telecommunications in Africa described above will change dramatically in the near future, opportunities exist now for Africans who want to make use of computer communications systems. The rest of this paper deals with the present state of computer communications in Africa, and opportunities to expand and improve these networking services.

Computer networks in Africa are growing, although not at a rate comparable with that of other regions. They are fairly developed in Northern African countries—such as Egypt and Tunisia—and in Southern Africa, where they even provide users with access to the InterNet through gateways situated in Europe and in North America. In other African countries, however, the networks are usually limited to store-and-forward technology and only provide Email and conferencing.

In the last four to five years, several electronic networks have been launched and operate with various degrees of reliability. One can cite NGONet Africa among NGOs, ESANET among Eastern and Southern African universities, ARSONet among African standards organisations, HealthNet linking medical institutions using low-orbit satellites, SATISNet linking institutions promoting appropriate technology, and UNINET-ZA spearheaded by Rhodes University in South Africa, which links the academic world in South Africa and neighbouring countries through UUCP and provides it with InterNet links. APC associated FidoNet nodes, often belonging to the above groups, cover a number of African countries not served by InterNet, providing access to InterNet mail and conferences through their GNFido gateway in London. RINAF supported by the Italian government through UNESCO and CABECA supported by IDRC at PADIS/ECA are attempting to cover the continent or large parts of it, although their realisation is not yet visible on the ground.

RIO, a network supported by the French overseas research organisation, ORSTOM, links research organisations, mostly in Francophone Africa, with their InterNet node at Montpellier, France. Among commercial networks, CGNet provides service to CGIAR (Consultative Group for International Agricultural Research) affiliated research centres as well as to UNDP and FAO field offices. The SITA group (Airlines Telecommunications and Information Services) network is open to other users than airlines but countries are often reluctant to allow SITA to operate beyond their original airline clientele.

Among other "closed" networks, some are operated by the UN. The GTS (Global Telecommunications System) operated by the WMO and Met departments, reserved for meteorological data transmission, links permanently Met Departments all over the world through leased lines. The UN Global Telecommunications Network has two main stations in Africa, one at UNEP Hq in Nairobi, the other at ECA in Addis Ababa. It is centered in New York and provides fast links to the UN Hq in New York and, through this, to the InterNet, but a link between the two stations does not appear to be part of the plan. There are also a number of private networks relying on X-25 or leased lines which are operated by transnationals.

Traffic flows through these networks depend on regular telephone, X-25 or leased lines. It is mainly North/South oriented, to Europe and North America. Except for InterNet nodes in South Africa, the gateway to other systems are in Europe, in line with telephone lines infrastructure, and frequently, when Africans communicate with each other, their messages pass through European nodes.

The development of African computer communications networks has been plagued by a number of problems: poor (or non-existent) telephone lines; very high cost of communications; poor power supplies; lack of encouragement or plain restriction from governments and P&T services; lack of awareness among potential users about the opportunities afforded by Email; shortage of computers and modems; lack of computer literacy in most professional environments; scarcity and unreliability of competent technical support services; lack of information on the networks specifically targeted to African users; and lack of collaboration and co-ordination among external support agencies, service providers and user communities.

As in other areas of development, the systems in place tend to be top-down, supply-driven rather than bottom-up, demand-driven. An observer recently characterised this situation as follows: "More emphasis has been placed on building up networking infrastructure than on supporting programmes with appropriate communications facilities. Yet, letters are written for substantive reasons, not because there is a post office which can carry them. Numerous networking programmes, richer in words than in resources, send missions, organise meetings and generally compete for users, time and skilled manpower. Each donor supports its own network, trying to carve out an identity and coverage from the same base, sometimes even using the same focal points. To note among others: SDN and INRES supported by UNDP, Infoterra supported by UNEP, CABECA supported by PADISNet/ ECA by IDRC, RINAF supported by the Italian government at UNESCO..."

Despite problems, for people who are determined, and who can convince others to join them in a collaborative effort, these constraints can largely be overcome. One example is the GHG Network of country teams involved in greenhouse gas inventories. With the support of GEF-UNEP and Climate Network Africa, these country teams have been provided with computers and modems, necessary software and training, and access to electronic communications nodes in their own or neighbouring countries. They can communicate regularly with each other and with resource persons in Europe through electronic mail and conference. A bi-lingual "conference" (or "electronic bulletin board"), called "africa.ghg", has been especially created for the African GHG teams and provides a dynamic forum for team members to exchange information and ideas.

The main point about this and other successful efforts in Africa is that it started with a small group of researchers and support agencies who have a need to communicate on a certain topic, i.e., greenhouse gas inventories. Such an effort requires collaboration and commitment of technicians, electronic system operators, and information providers (scientific teams, resource persons at IPCC, OECD, etc., and conference monitoring agents at Climate Network Africa and GreenNet-London). It utilises and builds on existing nodes and skills where available, and collaborates with other initiatives, e.g. GreenNet, CABECA, to provide services where they do not yet exist. Perhaps most important is that it is built on a knowledge of existing initiatives and a realistic assessment of what can and cannot be done in Africa at this time.

There are several conclusions to be drawn from this experience:

1. There is a need to shift approach from technology to purpose. It will be necessary to include electronic communications as integral parts of the activities which they are to support instead of trying to promote them per se, across the board and in a uniform manner. Only thus can users stay users and avail themselves of better tools to achieve their own aims.
2. Much of the information required by Africans is information generated by Africans. The GHG inventory teams have started with a methodology compiled in the North, and their discussions on GHGNet have mainly to do with specific problems related to adapting that methodology to African situations. Thus for our purposes, organising targeted information exchange within Africa may be more important than connection to the InterNet. Most of the information on the InterNet is not relevant to African users, and the cost in time and money for on-line searches for information that could be relevant is far beyond our budgets.
3. Successful communications systems for targeted working groups require "information brokers" with inexpensive access to Northern databases and InterNet conferences. The role of these "brokers" is to sift through the masses of available information, distill that of specific relevance to targeted groups in Africa, and put it on the relevant regional and international conferences. "Information brokers" are also needed to access specific documents upon request of African researchers and forward them by electronic or regular mail. For this to work efficiently and to the satisfaction of African-based users, the "information brokers" must belong to the same professional working group so as to be able to interpret queries while searching.
4. Cooperation is key to the advancement of good, low-cost communications. This could start at the UN level, e.g., with the UN agencies getting together to see how they can integrate their own systems and support their programmes with appropriate communications facilities. However, if Africa is to overcome the scourge of donor-driven programmes that don't meet Africa's real needs, they Africans have to cooperate among themselves to insist on the services they need. One obvious benefit of cooperation is that it would open up the option of sharing leased lines as user numbers grow to critical masses. Other, more immediate benefits would be user support groups to help newcomers to the system over the initial hang-ups; the more effective use of skilled computer technicians; creation of special conferences and support for "information brokers" to service the needs of specific interest groups; etc.

Conclusions and Recommendations

In traditional African societies, communication was essential to survival. Institutional frameworks developed for the preservation and transmission of knowledge and these formed integral and defining aspects of indigenous cultures.

In the modern world, communication is still essential to survival. Yet, as we have seen above, communication systems in Africa are in a sorry state.

Recommendations on how to improve the overall situation with regard to telecommunications in Africa have been made elsewhere (see, e.g. Habib Sy) and are beyond the scope of this paper. Our focus here is on what can be done now to improve communications among those working on climate science and policy in Africa. In this context, we recommend the following:

1. Include communications as a specific component in all climate programmes. All climate change projects and programmes, whether under IPCC, UNEP, WMO, UNDP, GEF, US Country Studies Programme or any other agency, should include a substantial communications component. Africans involved in preparing these programmes should clearly define their communications needs and request support for the facilities and "information brokers" required. The IPCC, specifically, should develop and support a programme to link its authors through electronic mail and conference and provide them with an information broker to service their specific information needs.
2. Build on African experience, expertise and existing structures, especially store-and-forward systems operating at present in most countries. The use of Northern computer communications consultants is limited, since their expertise has been developed under entirely different conditions and it is difficult for

them to update their field knowledge of options in fast-changing local situations. Successful experiences, such as GHGNet, can be taken as models.

3. Start the ball rolling by disseminating information on existing electronic conferences and forums as well as facilitating the participation of key contributors.
4. Establish national climate committees to information flow and access of all interested parties to the development of climate response strategies. Perhaps most important of all is acknowledgement of the need for cooperation among all of the different interest groups working on climate change. People will not communicate if they don't want to, and one has a strong feeling now that people don't want to. As long as climate change is perceived primarily as an opportunity to promote individual self interest, rather than as a crisis of significant proportions that requires the effective collaboration of all sectors of society, we will not develop the necessary collaborative structures and human capacity to support communications.

Information is power, to be concentrated or shared. The establishment of officially mandated national climate committees to provide fora for dialogue and information exchange, is a *sine qua non* for the formulation of climate response strategies that are compatible with national development priorities and sustainable development objectives.

Uganda Country Initiatives in Response to Climate Change

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It is now an accepted fact that climate change is a cross-cutting issue whose understanding calls for all the sectors to work together. Until recently there have been no nationally coordinated work on climate change although a lot of work whose main objectives were in investigating other Natural Resources issues has collected considerable data/information which is relevant to climate change studies. Some climate studies have also been done on the basis of ad hoc individual initiatives or as responses to specific queries or crises.

Included in the ad hoc studies are the impacts of temperature and rainfall. In this respect studies have been carried out using the available data sets. These have revealed considerable warming over the last 40 years especially to areas in South Western Uganda. In the case of rainfall, no significant trends indicating climate change have been detected. The most dominant signal is the inter-annual variability and this is Uganda's main concern at the moment. Furthermore, it has been found out that global forcings (like the sea surface temperatures) have a strong effect on climate variability in Uganda.

Uganda has just concluded a National Environment Action Plan (NEAP). The NEAP team was composed of eight task forces including a specific task force on Energy and Climate Change. The main environmental issues identified by the NEAP process and which have a bearing on climate change include land/soil degradation, deforestation, loss of biodiversity, poverty and energy related activities.

Uganda has just concluded a national inventory of greenhouse gases emissions and subject to availability of funding will soon embark on climate change vulnerability work.

Other climate related work which has been or is being done in Uganda includes the National Inventory of Wetlands, National Inventory of Ozone Depleting Substances, National Biomass Study (Inventory), National Case Study to Combat Drought and Desertification, and National Case Study on Biodiversity.

Because of these and many other studies, there does exist a lot of data/information which is relevant to climate change. Apart from the Department of Meteorology, another important centre in Uganda where relevant information could be got from is the National Environment Information Centre (NEIC).

In order to manage the environment, an Environmental Management bill is about to be enacted by the legislature.

Uganda subscribes fully to the notion that environmental initiatives should be nationally driven where the main actors should be at the grassroots in as far as is possible. Sometimes this noble objective is not so easy to fulfil due to donor conditionalities.

Finally, the case of fuelwood consumption in Uganda deserves special mention. Currently consumption is estimated at 17% beyond sustainable levels. For the majority of Ugandans, fuel wood is the obvious and in most cases the only choice because it is a free good worth no more than the labour and time needed to collect it. The Uganda NEAP is expected to address the unsustainability of fuelwood utilisation. Once more, sustainable solutions to this problem must be nationally driven. The solution, to be effective, must be culturally and ethically acceptable. The dissemination of affordable woodfuel efficient stoves may be the only short term answer to CO_2 emissions and sinks in this part of the world.

Climate Change Issues in Kenya

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Introduction

Climate change issues in Kenya can be discussed under four major subjects namely Science, Impacts, Mitigation Response Strategies and Issues Arising from the United Nations Conference on Environment and Development (UNCED) which was held in Rio de Janeiro (Brazil) in June 1992. Most of the approaches have been highly sectoral in nature.

Science of Climate Change

Climate change scientific issues which have been addressed in Kenya range from basic, applied to information science services. Most of the scientific efforts have addressed issues related to natural and anthropogenic systems associated with climate variability and change, together with the complex interactions and feedbacks within the total climate system.

Impacts of Climate Change, Mitigations and Response Strategies

Some attempts have been made in Kenya to examine the vulnerability of some of the socio-economic sectors of Kenya to climate change and variability. Most of these studies have been basically sectoral in nature and minimal efforts have been made to include the basic relationships between sectors. A good example is an examination of the vulnerability of agricultural systems without any attempt to include some components of the other major water use systems like domestic, industries, etc.

All these sectoral studies have used the IPCC global climate change scenarios which are quite unrealistic at national and local levels. Impact studies and mitigation strategies can only be meaningful if accurate climate change scenarios were available at national and local levels. These may not be available within the next few decades due to the chaotic nature of the climate systems and the new forcings from human activities. Sensitivity studies derived from extreme climate variabilities can, however, be used to quantify the potential impacts of some chosen climate change scenarios. Such information can be used to develop policy options for mitigating the negative impacts of climate variability and change.

Where Do We Go After Rio de Janeiro?

Since June 1992 a number of efforts have been made in Kenya to examine national obligations as per Agenda 21 and the Framework Convention on Climate Change (FCCC). Some healthy debates have also been going on at many levels regarding some of the sensitive FCCC areas which will be addressed by the First Conference of Parties which is to be held in Berlin (Germany) in March–April 1995. These include:

- National obligations like emission inventories and abatement strategies.
- Joint implementations of the Convention.
- Agreed full incremental cost of reducing emissions.
- Funding mechanisms which is currently being provided by GEF.
- Transfer of environmentally sound technology.
- Capacity building among others.

One of the major problems in many of the national climate change initiatives have been lack of close integration of the various efforts which has resulted in some duplication of activities. Many of the climate change efforts are heavily sectoral and are concentrated at public institutions, universities, private institutions, international organisations, NGOs like ACTS, Climate Network Africa, KNAS, KENGO, etc. and many individual scientists.

Some coordinations have, however, been provided by National Environmental Secretariat, National Environmental Action Plan, Kenya Meteorological Department, National Museums, sectoral research institutes, sectoral government departments, and many others.

Apart from lack of close interaction, the other major climate change problems have been related to **software, hardware, research funding, data and information, human resources** among many others.

Rapporteur's Report

GRACE AKUMU*

Monday, 18 July 1994

The meeting was chaired by Mr James Bruce, Co-Chair, Working Group III. Among the speakers were Prof. B. Bolin, Chairman, IPCC; Ms Elizabeth Dowdeswell, Under-Secretary-General and Executive Director, UNEP and Kenya's Permanent Secretary, Ministry of Environment and Natural Resources, Mr Sabari, who delivered a speech on behalf of his minister. Other speakers for the day were Dr Erik Haites, Head Technical Support Unit, IPCC Working Group III; Dr Youba Sokona, ENDA, Senegal; Prof. Richard Odingo, Vice-Chair, IPCC Working Group III; Ms Ann Heidenreich, Climate Network Africa; Shakespeare Maya, JVT Memorial Institute, Zimbabwe and Prof. Edith Brown-Weiss.

Prof. Bolin emphasised that in order to forge ahead, it was imperative for the Workshop to concentrate on providing knowledge to policy makers and to leave political discussions to country representatives attending the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC). He said that among the objectives of this regional session was to inform policy makers as well as to provide an opportunity for those working on the IPCC Report to learn strategies to address climate change from socio-economic considerations. He cautioned natural scientists not to underestimate other important aspects of climate change, i.e., its socio-economic impacts.

Ms Dowdeswell congratulated the IPCC for the distinguished work done in the last 4–5 years and reiterated UNEP's continued collaboration with the scientific body. The topic chosen for the Workshop she said, was important as Working Group III was being challenged to bring to bear social science on climate change due to the acknowledged complexity of the issues involved and whose uncertainties made it difficult for public policy makers to formulate policy. She stated that the new Rio Conventions, i.e., Climate Change, Biodiversity and Desertification demonstrated the need for synergy as the issues were intricately linked to one another.

Kenya's Permanent Secretary to the Ministry of Environment and Natural Resources opened the Workshop and welcomed all the participants to Kenya. He said that his country had been involved in environmental issues for quite some time and had taken part in the negotiations of the above mentioned Rio conventions (Climate Change, Biodiversity and Desertification). He pointed out that the Kenya government was in the process of ratifying the Climate Change Convention in preparation for the First Conference of the Parties. He valued the opportunity provided by the Workshop to exchange views and hoped that the topic would be given the due attention it deserved since environmental issues were closely intertwined with development matters. He said climate change readily highlighted this dictum. He reminded the participants that a large part of Kenya was threatened with desertification as well as the fact that Kenya was harbouring close to half a million refugees from neighbouring countries who were already posing serious environmental problems.

Prof. Odingo thanked the Kenya government, UNEP secretariat, the government of Norway and the Local Organising Committee for having made it possible for the Workshop to take place. He reminded the participants that the work was being done on behalf of the IPCC Writing Team.

Special Report

Mr James Bruce elaborated on the activities of the 10 groups of Working Group III. He said IPCC had been asked for a special report to be ready for the IPCC plenary which will take place in Nairobi, Kenya in October 1994 and for the First Conference of the Parties signatory to the Framework Convention on Climate Change which will take place in Berlin, Germany from 28 March–7 April 1995.

Dr Eric Haites outlined the structure of the report and was pleased that Working Group III had assembled some of the leading authors in social, natural and political sciences. He stated that Working Group III was a new aspect of IPCC established in November 1993. On the process by which IPCC works, he said that reports are reviewed by experts, peers and governments. He also mentioned that the panel of experts was

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selected in September 1993. He elaborated on the various chapters of the Second Assessment Report which will be out in September 1995 and would cover among others, decision making, applicability of costs and benefits, equity and social considerations, social costs of climate change, mitigation costs, emission scenarios, etc. He also indicated that Working Group III had held a series of workshops addressing various concerns and that the Nairobi workshop was the fourth one. The complete report he mentioned, would be considered by plenary session of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC) in Geneva in August 1994 and during the First Conference of the Parties to the Convention on Climate Change which will take place from 28 March to 7 April 1995. The reviewed document will be circulated to all the lead authors who will meet in Geneva in September 1994. The revised report will be circulated for peer review in October 1994 and government review would take place thereafter in December 1994 followed by approval by the IPCC plenary and publication of the same in late 1995, said Dr Haites. He said the IPCC Second Assessment Report would be completed by early 1995 and would deal with equity and social considerations. He read a statement on behalf of Dr Hoesung Lee who said that equity and socio-economic considerations are critical issues in developing appropriate response options to climate change. Dr Lee emphasised the concept of "common but differentiated responsibility" as stipulated in the Climate Convention with regard to inter-country equity. On intergenerational inequity, he reiterated the need for the current generation to act responsibly so as not to compromise the environment and development for future generations.

Institutional Capacity to Respond to Climate Change

A presentation was done by Dr Youba Sokona, Energy Specialist, of ENDA-Tiers Monde, Dakar, Senegal who said that with regard to African institutional capacity to respond to the provisions of the Framework Convention on Climate Change, he would base his remarks on field experience and programmes in which his institution had participated in.

The FCCC is an obligation for all countries. There is, therefore, the need for African countries to develop the institutional and financial capacity to respond and meet their commitments. African institutions should develop an offensive attitude to address climate change issues. At present, institutional capacity is weak or non-existent. Defensive stand is demonstrated in a number of cases, for example, it is often stated: "We would like to do this but no means". It is important to know the context in which this problem is placed.

In Africa, the improvement of living conditions and reduction of inequities is paramount. These should be addressed sectorally, i.e. energy, unemployment, etc. Food and energy constitute the life and growth of a nation. Problems of weakness in purchasing power of small farmers as well as states (local weaknesses) result in ineffectiveness to address global problems. There is need to increase energy consumption in Africa. Therefore the FCCC should undertake an in depth analysis on biological sciences and use of energy.

How do we in Africa deal with environmental problems, particularly climate change? The problem is often caused by deep problems of financial nature. The governments are for the time being managing on short term basis yet climate change problems are of global nature. There is a weakness in anticipating what will happen. There is a tendency to push environmental problems forward.

While at Rio the needs of environment and development came out clearly; Rio was not used as an opportunity to rethink development strategies. We have in Africa, different actors in climate change, i.e. government and/or government departments, multi-lateral or bilateral cooperation through finance and expertise, universities and non-governmental organisations. Governments as well as multi-lateral and bi-lateral organisations in Africa have a similar attitude to climate change: they are very reluctant to set up new and relevant institutions to address the issue. From a political point of view, climate change is not well understood. While from an international point of view, the African realities are not taken care of.

Initiatives

Local and effective initiatives which have public support and are acting as centres of excellence, taking into account African priorities and concerns and are engaged in awareness creation, sensitisation and networking are not taken into consideration by governments. For example, Climate Network Africa, a regional networking non-governmental organisation, run by a group of committed individuals and publishing regular policy briefs and a quarterly newsletter on climate change is not receiving assistance from any government. It is sad that their activities may be discontinued due to lack of financial support. Those of you who have read their newsletter *IMPACT* will agree with me that it would be sad to miss it.

There is therefore an absolute and urgent need to strengthen local capacities in data gathering and analysis, local projects, country programmes, technical assistance and long-term programmes as they rationalise the use of financial resources.

Consequently, it is crucial in Africa to initiate activities to address climate change by setting up relevant institutions. Climate change is in actual fact a problem of meteorology. Within the centres of excellence, identify needs, resources, competence, training, terms of reference, activity programmes for all these issues which have been elaborated.

Access to Information and Communications Networks

Ms Ann Heidenreich, Project Consultant/ Adviser, Climate Network Africa, presented a paper on "Equity, Communication and Climate Change: Access to Information and Communications Networks in Africa". She highlighted the communications problems in Africa at large and said that while Northern scientists working on climate science and policy had access to information and databases locally and intercontinentally, their African counterparts did not have the same privilege as ideology, costs and other barriers were placed on their way. She said that Northerners should stop perceiving climate change as an opportunity to promote self-interest but rather as a crisis of significant proportions that requires the effective collaboration of all sectors of society. To that extent she noted that it would be absolutely necessary for UNEP, IPCC, WMO, UNDP, GEF, US Country Studies Programme, and others, to include communications as integral parts of future programmes to address climate change issues. Africans should be allowed to define their communications needs. Prospective and/or potential donors should use African expertise and build on African experience while endeavouring to support existing structures. She stressed the vital role of communications as all societies considered it essential to survival.

National Climate Programmes

Prof. Odingo talked briefly on "Strategies for Integrating IPCC's Work into National Climate Programmes". He noted that climate change activities have come rather quickly and have caught African governments unprepared. He said climate change activities will only be meaningful if we have viable activities on the ground. Wild assumptions that African countries already had national climate programmes on the ground should be discarded. He observed that the IPCC process had introduced an interesting opportunity to participate in the climate debate. In collaborating with the IPCC, African countries should be prepared to participate fully in the process. The information on climate change would be used by each African country in various respects according to their needs and priorities.

National Strategies

Prof. Odingo further noted that coordinated programmes were lacking in many African countries in particular at the universities and meteorological services. Scope of interdisciplinary work was quite limited. There was no linkage of what these institutions were doing with those of the IPCC. Consequently, there was need for integrating work from various disciplines as global climate change had brought about the imperatives.

He said cooperation at regional level was important and gave examples of regional bodies such as ACMAD, AGRYHMET, etc. He criticised work being done by some OECD experts who come to Africa for three months and compile reports which are presented as "African positions". He called for truly African institutions which would begin to consider work on climate change in a serious manner and cited the work being done by Climate Network Africa (CNA) as an example that should be supported and replicated in other African countries. At the national level, he pointed out that at least African governments should begin by forming Interministerial Committees as well as National Climate Committees.

Panel Discussion on Country Activities in Response to Climate Change Related to Equity and Social Considerations

There were several speakers on the panel and they made the following contributions:

Mme Celestine Yatongo Prouva, Director, Environment Department, National Environment Programme, Ministry of Industry and Commerce, Central African Republic, noted that CAR is a landlocked country and that in the last few years, the government had been paying attention to post-Rio agreements and recommendations. They were all the same frightened by the fast-approaching Sahel. Before, CAR had one dry season and one rainy season. Now, it has two of each; causing a lot of anxiety to the citizens. She informed the Conference of the rampant dumping of toxic waste in her country by Northern countries. She, however, noted that most of the valuable work of the Conference would not be translated into French. She asked for a summary to be made in French so that French speaking delegates could have something to take home.

Dr Halassy Sidibe, Lecturer/Researcher, Mali, was concerned about authors at the national level. He thought there was a problem of terminology since in Mali there is a lot of talk of climate change as well as a lot of relevant sectoral data. He stressed the need to encourage Africans to publish more.

Prof. Laban Ogallo, Professor of Meteorology. Department of Meteorology, University of Nairobi, and National Council for Science and Technology, Kenya, pointed out that climate change activities in Kenya are done in individual sectors e.g. science, impacts, mitigation response strategies and issues arising from the United Nations Conference on Environment and Development. He cited lack of integration of various efforts to address climate change which sometimes resulted in duplication of activities. He also pointed out that most of the work on climate change in Kenya was heavily sectoral and was concentrated at public institutions, universities, private institutions, international organisations, NGOs, i.e., ACTS, Climate Network Africa, KNAS, KENGO, etc., and individual scientists.

He noted the lack of basic information on the science of climate change at national level but equally decried the use of foreign methodologies, i.e., the OECD/IPCC methodology for national inventories. He said NGOs had taken the lead role in 'where do we go from Rio?'

He stressed that other than close interactions, the other major climate change bottle-necks were related to software, hardware, research funding, data and information, human resources, etc.

Dr Isabelle Niang-Diop, Geologist, Cheikh Anta Diop University of Dakar, Senegal, member of the National Committee on Climate Change which groups together individuals and researchers. She pointed out that there was a lot of work that was being done in Senegal with regard to impact of climate change on food security, impact of climate change on the acceleration of sea level rise, etc. It was important to recognise that all these studies related to problems from the North. She criticised Northern researchers who come to work with Africans but insist on setting the agenda and priorities. This renders African researchers inactive and creates dependence apart from changing the objectives. She said that as a result of African governments being faced with the stark reality of basic survival of their citizens, they were only interested in day to day plans vs long term plans. If immediate measures are not taken to address the nature in which climate change issues are presented to governments, then very soon we shall be preaching to deserts. We must agree to address economic issues first. That is what is of concern and top of priority to African governments. For example, instead of the North providing funds to African governments to develop themselves, they prefer to provide funds to reduce population; sometimes with sheer disregard to local religious beliefs, traditions and cultures.

Dr Francisco Mabjala, Head of Department, National Environment Commission, Mozambique. As a result of the long war situation in the country, not only nothing on climate change has been done, but equally in other sectors too. Mozambique's priority is food supply. After Rio, there has been coordination with other government departments, i.e., energy and agriculture. Recently the Climate Convention was submitted for ratification. The US Country Study Team has recently visited Mozambique. The country is vulnerable to climate change as it has large coastlines and the economy depends on marine resources. Access to information on climate change is a major problem as the country is Portuguese speaking yet most documentation on climate change is in English. The country receives documents in English only and the capacity to use them is limited.

Dr Bright E. Okogu, OPEC representative, Austria, noted that in the process of development, energy is needed. In the process of using energy, the environment is degraded. In countries with low GDP, there is a tendency to have a large population. This draws a clear linkage between population and poverty. The government of Nigeria currently has a plan to reduce the number of children, i.e., to four per family but nobody will listen to a government whose priority is to reduce the number of children per family instead of providing the basic necessities. Therefore, the citizens will continue to make more children for security.

Pricing of Energy

Dr Okogu said that there was need to have a fair price which reflected externalities. In Nigeria, the emphasis is not on greenhouse emissions, the emphasis is on basic economic survival. The Nigerians perceive their problems as being of priority. Any talk of climate change in Nigeria is laughed at because it is not of priority to the people. Energy pricing policy tends not to reflect the cost of production.

Institutions

Climate related institutions in Nigeria tend to be more like civil service. Coordination is quite poor. Linkage is almost nonexistent. Data gathering is a major problem.

Oil Spillage

Communities where oil is produced are ignored.

Gas Flaring

The infrastructure of gathering gas from the flared gas is a problem.

Prof. Mark Mwandosya, Director, Centre for Energy, Environment, Science and Technology, Tanzania. There is need to understand what is going on and to formulate sectoral policies to allow for adaptation and mitigation strategies. Climate change is by its very nature, interdisciplinary. Synergies among sectors are part of the solutions, e.g. a sound energy/agricultural policy involves rational use of resources.

NGO evolution has led to formation of centres of excellence in resource use and management, e.g. the Southern Centre for Energy and Environment; Centre for Energy, Environment, Science and Technology; etc. These centres have started not as a result of international needs but internal needs and dictates to address policy analysis as well as global climate change. While these centres are small, they collectively provide the institutional framework around which institutional capacity building to address climate change can be addressed. These institutions are already addressing: inventories, adaptations, vulnerabilities, etc. They have also embarked on mitigation and response strategies. Prof. Mwandosya commended Climate Network Africa for its commitment to networking and added that CNA's *IMPACT* newsletter was very useful to Africans working on climate change issues and as an information tool.

Prof. Bolin, reacted by pointing out that the need for Africa to develop is a priority. This was also mentioned in the Framework Convention on Climate Change. He expressed regret that climate variation had not been mentioned so far during the day's deliberations. He said climate variation was worse than climate change. Today, we could not explicity point to changes due to climate change. Therefore, climate variability and its role should be part and parcel of country studies.

He also remarked that it would be interesting to know plans for expansion of energy supply countrywide. It would be useful to know what various countries of Africa are thinking. Equally, it would be useful to know about the dependence of national economies on various sectors and their impact on climate change.

Mr Aubrey Meyer, Global Commons Institute, UK, cautioned the preponderance of economists working on IPCC Working Group III to try to keep the issue of emissions global while emissions which need to be mitigated are not global in the first place but confined to certain geographic areas.

Mr R.S. Maya, Director, Southern Centre for Energy and Environment, Zimbabwe. Climate change activities particularly those relating to greenhouse gas emissions assessments and emissions abatement options have received greater attention from our scientists and have received greater financial support from the North. The flip side of these activities, vulnerability assessments and adaptation options have received much less financial support and therefore research effort. The latter pair, vulnerability and adaptation are more important to Africa. But besides this fact and the fact that developing countries have argued successfully that accumulation of GHGs is not attributable to them, inventories and adaptation of secondary importance to Africa have retained greater attention. This points to some institutional weaknesses in Africa that should be corrected to allow African scientists to pursue first those issues closer to their interest in this new international cooperation model.

The presence of African scientists or researchers in shaping leading opinion on issues shaping international models of cooperation in climate change remains limited. For example, on the new paradigm of joint implementation, particularly North-South joint implementation, it is quite possible to identify a Latin American position as well as an Asian position. There is, however, virtually no evidence of an African position.

The interdisciplinary and sectoral consultations on issues of national responses to climate change could also be improved. Experience at Southern Centre for Energy and Environment in Harare under the UNITAR training programme for senior policy-makers on climate change has shown a significant divergence of appreciation of social and economic issues related to climate change impacts and responses.

The concept of centres of excellence which has been alluded to earlier by some speakers perhaps need to be taken up seriously in order to enhance Africa's preparedness for the various physical, economic, social and political imperatives inherent in global collaboration to mitigate climate change and its impacts.

Keynote Papers

Chair : Mark Mwandosya

Rapporteur: Ann Heidenreich

Science, Values and Climate Change

BERT BOLIN*
Chairman of the Intergovernmental Panel on Climate Change, IPCC

Background

The discussions at this Workshop on social considerations and equity in the context of climate change should be conducted in full awareness of the key characteristics of the global environmental system and its expected changes due to man's increasing activities on earth. Also, we need to consider the mutual interactions between two complex systems, the global environmental system and the global socio-economic system, that both are chaotic, i.e. their future detailed changes are in principle unpredictable beyond some rather limited time into the future. Therefore, we need to analyse carefully what can be said about the future with some confidence and what can only be assessed statistically.

Complex, Chaotic Systems, General Considerations

We are concerned with:

- *The global climate system* that includes the atmosphere, the oceans with their marine ecosystems, land with its top soil and terrestrial ecosystems and the cryosphere, i.e. ice sheets, glaciers and sea ice.
- *The global socio-economic system*, i.e. the people of the world grouped in a number of countries in very different states of development and social structure and with different cultural traditions that have evolved over centuries and millenia.

Such systems are characterised by inherent instabilities, the occurrence of non-linear interactions and oscillations and the possible existence of several equilibria, around and between which they may oscillate. They are for these reasons commonly called chaotic. The predictability of their behaviour is limited, although the range of variations of key variables is usually reasonably well constrained by their overall characteristics. External boundary conditions such as forcing from the outside, as for example in the case of the climate system, are important in this context.

In addition to being chaotic these systems are very complex. Changes in the climate system occur on all space scales that the domain embraces i.e., from molecular to global space scales and on time scales from seconds to centuries or even more and also, a large number of physical, chemical and biological processes play a role. Similarly, the socio-economic system includes all people and countries in the world and we are here concerned with time scales up to at least centuries.

Instabilities can occur on different spatial scales in a complex, chaotic system and energy transfer from one scale to another implies the possible activation of large scale instabilities by processes on small scale. We can view the hurricane as a typical example of how small scale convection over the ocean becomes organised into a larger scale structure and permits a formidable release of kinetic energy on this larger scale. The development of worldwide economic depressions is an example of how more limited economical crises may become of global importance through an interplay within the socio-economic system. Old societal structures collapse and may make room for new developments.

It is of course legitimate to ask the question: Is it at all possible to develop concepts and models that deal with such complex systems in a meaningful way? Are we able to consider their interaction and expect useful results? The answer is not a straightforward "Yes". Some aggregate features may be predictable, while detailed changes probably often can only be described statistically. It is important to analyse what can be achieved in this regard and what cannot. We need to approach the climate change issue much more in terms of risk analyses.

The Climate System

Three-dimensional climate models have developed from weather forecasting models. It was realised already in the 1960s that the limit of predictability of the weather system is only about ten days to two weeks and that details of the

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weather can only exceptionally be foreseen beyond a few days. For example, the predictability of rain showers is limited to a few hours.

When, however, computers became powerful enough to permit the application of such models to the globe system as a whole, it became meaningful to address another problem: Can we derive the *statistical behaviour of the weather* on the earth and thereby *determine the distribution of climate?* Already the first attempts to address this question some twenty-five years ago showed positive skill. Since then, more detailed and refined models, that include much improved sub-models also for the oceans, have been used. The results derived with the aid of present day models are most encouraging (Manabe et al., 1991, 1992).

The spatial resolution of such models has usually been 300–500 km in the horizontal and 1–2 km in the vertical. This means that processes on smaller scales can only be included statistically. Dissipative processes must also be included properly and they, similarly, operate on smaller scales. The uneven distribution of solar radiation means differential warming, which creates potential energy that in turn is transformed into kinetic energy, i.e. winds in the atmosphere and currents in the oceans. Dissipation of kinetic energy keeps these motion systems within bounds.

Climate simulations are carried out as weather forecasting experiments for decades, perhaps even a century. Not only are mean conditions derived in this way, but also the statistics of the variations of meteorological variables, the occurrence of extreme events and statistics of ocean behaviour in general. We find that the model climate, as averaged over one or a few decades does not remain constant. These are all features that compare reasonably well with observations of the real weather and climate on different time scales, which certainly adds further credibility to the models.

It is more difficult to validate experiments that aim at deducing changes of climate due to prescribed changes of external parameters such as the amounts of greenhouse gases in the atmosphere. We cannot compare the results directly with observations, since we have never before observed a rapid increase of the amounts of such gases in the atmosphere as is the one now occurring. Further, the computed changes lag behind the equilibrium change. This delay depends on the slow warming of the ocean. We cannot validate quantitatively this finding directly. Indirect support can, however, be derived by analysis of the uptake of the oceans of radioactive tracer gases emitted into the atmosphere by man, which process is similar to that of heat uptake (cf. Siegenthaler and Sarmiento, 1993). It is also important to find out if the daily and seasonal variability of temperature, precipitation and wind and frequency of occurrence of extreme events might be different in a warmer climate, since impacts of climate change on ecosystems as well as on man much depend on such climatic characteristics. We are, however, again not able to validate such model results against real changes in the past.

We also know that non-linear oscillations may be activated in chaotic systems. Is it likely that this may happen in the case of a general shift towards a warmer climate? Some observations of past changes of climate are of interest in this context. The course of the Gulf Stream seems to have been changing quite rapidly back and forth in the northern Atlantic during the retreat of the major northern hemisphere ice sheets 10,000 to 11,000 years ago. Experiments with interacting atmospheric and ocean models show that a change of the frequency of precipitation and associated changes of the surface water salinity over the northernmost Atlantic Ocean might initiate non-linear oscillations with a quasi-periodicity of about 400 years (Mikolajewicz and Maier-Reimer, 1990). We do not know if this might be of relevance in the context of future man-induced changes of climate, but we should be aware of the possibilities that such unexpected events might develop in a warmer world.

Although there is considerable uncertainty about the climate change scenarios that have been derived for the next century, it seems plausible that the broad scale features of the deduced changes can be used to judge in general terms how serious a future change of climate might be. We are, however, not able to deduce more detailed scenarios that can be used for determination of the specific impacts of a climate change regionally. Statistical results may, however, be derived. Analyses of global ecosystem sensitivity to changes of climate show, for example, that some 15% of the ecosystems we today find on land might well be replaced by other ecosystems in case of a climate change caused by doubling of carbon dioxide (Prentice and Sykes, 1994), but we still cannot foresee which regions would be primarily hit.

Because of these characteristics of the global climate system we are not able to tell more precisely what the effects of a climate change might imply for man and his global society. We might perhaps in a decade be able to validate the more detailed theoretical scenarios against observed changes that can be attributed to the enhanced greenhouse effect and thereby gain more confidence in the detailed patterns of change as derived by model computations. Some parts of the future changes in climate will, however, always remain unpredictable and it is important to understand better its magnitude. The inertia of the socio-economic system and its slow response to mitigation efforts means, however, that we hardly can delay preventive actions long and we need to base appropriate actions on risk analyses.

Finally, we summarise our present more specific knowledge as follows (cf. IPCC Climate Change, 1990, 1992; IPCC Special Report, 1995):

- Atmospheric carbon dioxide concentrations have increased from about 280 ppm (parts per million) about 200 years ago to 358 ppm at present, i.e. a total increase of about 28%. The annual increase is on average about 1.6 ppm but varies considerably from one year to the next.
- Atmospheric methane has increased from about 0.75 ppm early last century to a present value of about 1.7 ppm. The last annual increase by about 1% has diminished during the last few years, presumably at least partly due to less leakage in the process of natural gas exploitation and transport.
- Other greenhouse gases, dinitrogen oxide, and man produced CFC- and HCFC-gases have also increased in concentrations during the last half century. The rather stringent restrictions on the use of CFC-gases, that have been agreed on because of their destructive effects on the ozone layer, have significantly reduced their rate of increase. The HCFC-gases now are rapidly replacing them. They have much shorter residence time in the atmosphere and are therefore less potent as greenhouse gases in the atmosphere, but their future role must not be ignored.
- Tropospheric ozone has increased significantly in presently developed countries since the beginning of the Industrial Revolution. It has probably doubled or even tripled in heavily industrialised regions. Stratospheric ozone, on the other hand, is decreasing because of the catalytic effect initiated by the increasing concentrations of CFC-gases.
- Man-induced emissions of aerosols, due to the emission of sulphur dioxide from fossil fuel burning in industrialised countries and forest and grassland burning in the tropics, on the other hand, reflect solar radiation. Their regional distribution is, however, very patchy and therefore they compensate the enhanced greenhouse effect due to emissions of greenhouse gases only partly and regionally.
- The total enhancement of the greenhouse effect so far due to the emissions of gases and aerosols corresponds to an increase of carbon dioxide by 25–40% in the northern hemisphere, but rather 35–45% in the southern hemisphere, where the emission of aerosols play a minor role.
- Experiments with global climate models show that the man-induced enhancement of the greenhouse gases in the atmosphere, equivalent to the doubling of the concentration of atmospheric carbon dioxide and also considering the associated increase of atmospheric water vapour due to the warming would increase the mean global equilibrium temperature of the earth's surface by 1.5–4.5°C.
- The inertia of the climate system implies, however, that the temperature change realised at present is merely 50–60% of the computed equilibrium temperature change at any one time, but it will ultimately be realised, if and when the greenhouse gas concentrations in the atmosphere are gradually stabilised.
- The mean global surface temperature has increased by 0.4–0.6°C during that last century compared with 0.3–1.1°C as deduced with the aid of climate models.
- The change of climate is not going to be equally distributed over the earth's surface but regional differences will emerge. Probably the temperature increase will be most marked in the interior of continents at middle and high latitudes. Also, in spite of a likely intensification of the global hydrological cycle, precipitation over the interior of continents might not increase but rather decrease resulting in less soil moisture.

The more precise characteristics of a climate change will probably be obscured well into the next century due to the natural variations of climate. Estimates of the likely impacts on natural ecosystems and on the countries of the world due to climate change will remain uncertain for quite some time.

The Socio-Economic System

General Considerations

The socio-economic system is also a chaotic system in the sense that marked non-linear events and discontinuities occur. The obvious tendencies for economic crises to develop locally with strikes, lock-outs and sometimes the collapse of individual industries, or even nations, are signs of such non-linearities. It is also qualitatively well known that local crises may develop into regional ones. The most extreme crisis of society is of course war. It is, on the other hand, important to emphasise that a chaotic system implicitly also provides for innovation and renewal.

Most of these events are far beyond what socio-economic models at present can deal with, which means that predictions of the more detailed behaviour of socio-economic systems are not possible. Economic modelling is built on assumptions that equilibrium market conditions is maintained and direct consideration of social matters are usually not included, even though we know that such factors play an important role for change and development. Present macro-models of the global socio-economic system should therefore rather be considered as tools to describe the development of society largely without much social considerations and equity concerns and with disregard of the development of regional or global crises. They can also be used for sensitivity of the socio-economic system to key economic variables, such as change of GDP (Gross Domestic Product), energy intensity (energy used per unit of production), carbon intensity (emissions of carbon dioxide per unit of energy used) and population increase.

It is important to realise that the concept of equity needs careful definition. There may for example be important cultural differences in the meaning of the concept. We need to distinguish between inter-national and intra-national equity. The present discussion will, however, be limited to *international equity*. In that context it is also of interest to consider the issue of *intergenerational* equity.

The issues of social considerations and equity in the context of climate change concerns:

- The way countries and people will experience a forthcoming climate change and the needs for and possibilities of adaptation.
- The sharing of responsibilities between countries with regard to measures to be taken to delay or prevent climate change.

Social Considerations and Equity in Assessing Impacts and Adaptation

It is clear from the previous section that the seriousness of a climate change impact will vary much from one country to another.

The effects of a rising sea level will obviously only hit coastal countries. It should, however, be recalled that the sea level is also influenced by ocean currents and if these will change markedly, the sea level may also be influenced up to 10 to 20 cm. In some cases slow isostatic movements of the earth's surface will either compensate the rising sea level (particularly in countries which were covered by ice sheets during the last ice age, e.g. Canada, Scandinavia) or make things worse (e.g. NE US, England and the southern coast of the North Sea). Low lying islands in the tropical regions are obviously particularly threatened. How should equity be dealt with in cases of this kind?

Changing patterns of temperature and precipitation over land will change the possibilities for agricultural and forest production. Again some countries may profit, although the majority will probably suffer. It is not possible as yet to tell who will be losers and winners. This will only become clear slowly, even though some features of the geographical distribution of a possible climate change is already emerging (cf. earlier sections). To what extent will such matters influence the relative responsibilities of countries?

Social Considerations and Equity in Mitigating Climate Change

The Climate Convention prescribes, in Article 2, that the ultimate objective of the convention is

> "...stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

A *more immediate goal* is also *defined* for developed countries, i.e., to stabilise emissions of greenhouse gases by the year 2000 at the 1990-level. Countries are supposed to report to the first session of the Parties of the Convention about measures that will have been or will be taken to meet this objective.

The Climate Convention prescribes that in developing mitigation strategies all greenhouse gases should be considered simultaneously in order to minimise costs. The following comments will, however, be limited to the consideration of emissions of carbon dioxide caused by the burning of fossil fuels and changing land use, since they presently contribute about 60% to the enhancement of the greenhouse effect, which figure will probably increase further during coming decades. The prevention of a change of climate is therefore obviously closely related to the use of fossil fuels in providing for the future energy supply for the world.

The contributions by different energy carriers to the world energy supply today is given in the following table (World Energy Council, 1993):

Energy source	Percentage	
Fossil fuels		77.2
Coal	26.1	
Oil	31.8	
Natural gas	19.3	
Renewable, traditional[1]		10.3
"New" renewables[2]		2.3
Hydropower		5.7
Nuclear		4.5

[1]Primarily developing countries.
[2]"Modern" biomass, solar, wind, geothermal, oceanic.

About 45% of the total energy supply is used by developed countries, 21% by former Soviet Union and East-European countries and 34% by developing countries, while their parts of the world population were 17, 7 and 76% respectively.

Almost 90% of the increase of world energy use now takes place in developing countries, in particular in southeast Asia and China. This rate of increase implies that these countries, within less than 20 years, may make use of more than 50% of the world energy supply, but as their populations also will increase, their per capita use will still at that time hardly exceed 20% of that used by developed countries. The 1990 inequity with regard to exploiting natural energy resources is shown in the following table, but the question will arise: In which way will a continued rapid increase of the population in developing countries be considered in attempts to more equity in a future world?

Region	1990 per capita energy supply kWh per year	kW
North America	91,000	10.4
East Europe and former Soviet Union	52,000	5.9
Western Europe	37,500	4.3
Pacific, including Japan	30,000	3.5
Latin America	15,000	1.7
Middle East, North Africa	13,500	1.6
Southeast Asia, including China	10,000	1.2
Sub-Saharan Africa	6000	0.7
Southern Asia	4500	0.5
The Rest of the World	19,500	2.2

Experiments have been made with macro-economic models in order to determine the most effective means of stabilising and also reducing greenhouse gas (particularly carbon dioxide) emissions. Improving energy efficiency both with regard to provision and end-use of energy is commonly derived as important, in particular during the next few decades, while environmentally benign energy supply systems are being developed for possible introduction. In many such analyses, however, improving equity between the countries of the world has not been prescribed as a side condition. This naturally leads to difficulties for developing countries for example because of declining use of their natural resources (for example oil and coal), which often are a main source for their income and thereby means for development. More penetrative studies are needed of how to stabilise, or even reduce, global greenhouse gas emissions (especially carbon dioxide) and simultaneously ascertain sustainable development and equity between countries of the world.

About 70% of present carbon dioxide emissions due to fossil fuel use comes from developed countries. Their emissions since the beginning of the industrial evolution amount to about 85% of the total emissions. Only about 45% remain in the atmosphere (airborne fraction) and the oceans has served as the prime sink for the rest, while the net decrease of the carbon content of the terrestrial ecosystems due to deforestation and changing land use probably has been considerably less. The uptake by the oceans is a gradual process. The early emissions to the atmosphere have largely gone while most of the recent emissions still remain in the atmosphere leading to an airborne fraction during any one year to be about 45%. Since the contributions by developing countries are relatively recent, the relative contributions from developed countries to the *present enhancement of the atmospheric carbon dioxide concentration* is less than 85%, but of course more than 70%, presumably somewhere between 75 and 80%. Available carbon cycle models can be used to determine more precisely how to determine the relative responsibilities with due regard taken to the intergenerational equity.

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Meanings of Equity

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Climate Change: Impacts and Response Options

Why socio-economic considerations?

- Because the **causes** of climate change are **economic,**
- though the **effects** are physical and biological.
- Since the effects are physical, economists underestimate them.
- Since the causes are economic, physical scientists cannot find solutions.

Climate change requires thinking and acting across disciplines.

Through climate change humans have turned the tables on nature.

For the first time in recorded history economic activity has reached dimensions at which it changes the atmosphere of the planet and its biodiversity.

The most important climate risks today are induced by human action.

Why Equity?

- Because both the causes and the effects of climate change are closely linked with equity and inequity in the use of the global commons.
- The North's economy represents the main **cause.**

It has used, and continues to use, most of the global resources and environment:

- produces 70% of all CO_2 emissions,
- consumes most forest and mineral products,
- emits most *CFCs.*
- The South suffers most of the **effects:**

It is most vulnerable to effects of climate change

- on food production, and
- on living conditions.

The North produces most risks, and the South bears them most.

Economic Development Based on the Satisfaction of Basic Needs Sustainability

- Basic needs were introduced (Chichilnisky, 1974, 1977) to rethink development patterns, so they would be consistent with environmental constraints.
- Bariloche Model (1974–76) and sustainability
- Bruntland Report, needs and sustainability

Climate Change is Global

It therefore requires us to focus on

- Global socio-economic issues
- Global equity.

State of the Art

- Economics is weak on equity issues.
- It is also weak on intergenerational concerns.

Why?

The weakness on equity comes from focusing on **markets with private goods,** in which efficiency is divorced from distribution.

The weakness in intergenerational justice comes from the use of **discounted welfare criteria** to maximise value across time. Discounting the future leads to undervaluing future environmental assets.

Markets

Markets are the dominant institutions in modern industrial economies.

Markets are supposed to work efficiently independently of the distribution of income.

What is Economic Efficiency?

Total resources: $\Omega \in R^N, H$, people, each with a preference $u_h: R^N \to R$. An allocation $\Omega_1 \ldots \Omega_H \in R^{N \times H}$ is feasible if $\sum \Omega_h = \Omega$.

A feasible allocation is **Pareto efficient** if there is no other feasible allocation which makes everybody ($h = 1...H$) as well off, and some strictly better off.

A market is $E = \{R^N, u_h: R^N \rightarrow R, \Omega_h \in R^N, h = 1,...,H\}$ where $u_h: R^N \rightarrow R$ is the preferences and Ω_h the property rights of the *hth* trader on the *N* private goods.

A **competitive equilibrium** is a price $p^* \in R^N$ and an allocation $x_1,\ldots,x_H \in R^{N \times H}$ such that each trader maximises utility subject to a budget constraint:

Max $(u_h(y))$ for $y \in \{z \in R^N: \langle p^*, z\rangle = \langle p^*, \Omega_h\rangle\}$ and markets clear:

$$\sum_{h=1}^{H} x_h = \sum_{h=1}^{H} \Omega_h.$$

First Theorem of Welfare Economics:

The allocation resulting from a competitive market equilibrium with private goods is Pareto efficient.

This theorem is independent of the distribution of property rights

$$\Omega_1,\ldots,\Omega_H$$

For example: All but two traders may have zero endowments of property rights and the resulting equilibrium is still Pareto efficient. But it requires all traded goods to be **private goods**, with rival consumption, and privately owned.

Public Goods Change Matters

A **public good** is a good which is not "rival" in consumption: This is not an economic or legal definition but rather a physical constraint. The allocation of the public good must be the same for all.

Examples: the concentrations of CO_2 or *CFCs* in the atmosphere of the planet; biodiversity in the planet. Environmental assets are generally public goods.

CO_2 concentration in the atmosphere is a quintessential public good because it is mixed very thoroughly and stable.

It is not a typical public, because it is **privately** produced.

A Competitive Market with Property Rights on Environmental Assets

An economy has *H* countries or traders who consume *N* private goods and one public good, *a*, the quality of the atmosphere. They trade private goods $x \in R^N$ and the rights to emit gases (CO_2) into the atmosphere. The more goods they produce the more energy they use, and the more carbon they emit, or the less *a* they **abate:**

$$x = \phi(a_h), \phi' < 0.$$

Countries (or traders) have property rights $\Omega_h \in R^N$ on private goods, and also property rights on the use of the atmosphere, such as total rights to emit, $\overline{a_h} \in R$, and preferences $u_h: R^{N+1} \rightarrow R$. They may use their rights to emit or trade these rights in the market.

Market Equilibrium with Emission Rights

Each trader chooses x_h and a_h to

Max $(u_h(x_h, a))$

subject to

$$px_h = \phi(a_h) + q(\overline{a_h} - a_h);$$

the value of consumption equals the value of production plus the permits they buy or sell, and all markets clear:

$$\sum a_h = \sum \overline{a_h} = a.$$

A competitive equilibrium is defined as before, but there is one additional **physical** constraint:

The market allocation of the public good $(a_1,\ldots, a_H)$ R^H must be the same for all $\forall h,h'$:

$$a_h = a'_h$$

Theorem 1

(Chichilnisky et al., 1993):

There is only a finite number of ways of distributing property rights on environmental use between the traders so that the market equilibrium is Pareto efficient.

Policy:

Those who have fewer endowments of private goods must be endowed with more property rights on the common environmental assets. Otherwise the market cannot operate efficiently:

- Efficiency and distribution are closely connected in economies with environmental assets.
- Equity is necessary for efficiency.

What about intergenerational justice?

What about distribution between the present and the future?

Can markets value properly environmental assets?

Axioms for Sustainability

Chichilnisky, 1992, defines rigorously two formal axioms to evaluate welfare across generations:

- **No dictatorship of the present**
- **No dictatorship of the future**

These axioms exclude discounted utility and all other welfare criteria used until now: overtaking criterion, Ramsey's criterion, long run averages, Rawlsian criterion.

Yet there exist welfare criteria which satisfy both axioms, and I call **sustainable preferences**.

Theorem 2

(Chichilnisky, 1992):

These two axioms fully characterise a welfare criterion of infinite streams of utility

$$\alpha = (u_1, \ldots, u_t, \ldots) \in \ell_\infty :$$

$$W(\alpha) = \sum_{t=1}^{\infty} \delta(t) u_t + \phi(\alpha)$$

where $\phi(\alpha)$ is like the long run average and puts all the weight at infinity and

$$\sum_{t=1}^{\infty} \delta(t) < \infty.$$

Theorem 3

(Chichilnisky, 1993):

There exist intertemporal problems where the optimal solution according to a sustainable preference does not maximise the present value of intertemporal profits, for any discount factor.

Policy:

Sustainable solutions may not maximise market value. Sustainability and markets define different value systems.

- Maximisation of present value is inappropriate as an intertemporal welfare criterion.
- Discounted cost-benefit analysis is not adequate to evaluate long lived environmental projects.
- The preservation of long run stocks (forests, biodiversity, atmosphere quality) must be considered in addition to present value of the policy, and its physical feasibility must be evaluated with cross disciplinary methods.

Who is the Future?

- Sustainability and global consciousness.

Global Warming and the International Fund for Atmospheric Stabilisation

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Abstract—The equity considerations loom large in the analysis of economic, social, and political implications of various policy and institutional measures for global environmental issues, particularly for global warming. The problems concerning the equity in relation with global environmental issues have two distinct features: intergenerational, on the one hand, and international, on the other. While the current generation benefits from the consumption of fossil fuels which contributes to an increase in the atmospheric concentration of carbon dioxide and other greenhouse gases, it is the future generations that have to suffer from the phenomena caused by the atmospheric instability, such as global warming and other climate changes. By the same token, it is the developing countries which mostly benefit from those economic activities that cause atmospheric instability, while it is the developing countries which have to bear the burden of climate change and other associated phenomena.

Traditional economic theory, however, has not given us a framework sufficiently broad enough to deal with the economic implications, from the equity point of view, of various phenomena of environmental disruption, particularly of global warming and the loss of biodiversity. The concept of dynamic optimality, typically applied to assess the welfare implications of processes of economic development, entirely disregards the distributional aspects of the allocative process and exclusively focuses its attention upon the Pareto-optimality of intertemporal allocations of scarce resources. The system of optimum carbon taxes introduced to ensure the dynamic optimality of intertemporal processes of resource allocation necessarily implies that the identical rate has to be charged to the emission of carbon dioxide regardless of the country where it is emitted. Thus, if the carbon tax at the rate of $170 per ton, in the carbon content, of carbon dioxide emitted is charged in the United States, then the same rate of $170 has to be charged in Indonesia and the Philippines. The per capita assessment of the carbon tax then would be about $600 in the United States, where the per capita level of national income is $17,000, while it is about $170 in Indonesia where the per capita level of national income is $400, and, in the Philippines with the per capita level of national income $500, it is about $500, with disastrous implications for all economic, industrial and urban, activities in Indonesia and the Philippines.

In contrast to the concept of dynamic optimality, the recently introduced concept of sustainability takes into consideration equity and distributional implications of processes of economic development, paying particular attention to the qualifying constraints that the distributional equity is satisfied at each moment in time.

In the present paper, we should like to introduce those institutional measures, in the form of differentiated carbon taxes, which would guarantee that the ensuing processes of intertemporal resource allocation are sustainable and at the same time they are approximately dynamically optimum, meaning that the processes of intertemporal resource allocation approach the long-run stationary state of the atmospheric concentrations of carbon dioxide and other greenhouse gases which are optimum in terms of the intertemporal preference ordering prevailing in the society.

The basic analytical apparatus we will be applying in the present paper is that of the dynamic theory of optimum resource allocation, as originally introduced by Ramsey, Koopmans and Cass, and later extended by Mäler and Nordhaus to the situations where the environment plays a crucial role in the processes of economic development.

Global Warming and Atmospheric Disequilibrium

During the past two decades, meteorologists, geophysicists, and geochemists have continuously warned us about the existence of numerous symptoms which indicate that the atmospheric equilibrium is disturbed on the global scale. Global warming is one of such symptoms which exerts enormous implications for virtually every aspect of human life on the earth, affecting not only the current generation, but also involving all future generations.

The extent to which the phenomenon of the global warming has occurred may be best indicated by the global average surface air temperature, which has significantly risen during the period of some two hundred years since the Industrial Revolution, at an accelerated pace in the last decade. According to the report recently issued by the Intergovernmental Panel on Climate Change (IPCC), the global average surface air temperature would most likely be 1°C higher than the present level by 2025, about 2°C higher than pre-industrial level; a disturbing phenomenon if we take note of the fact that the global average surface air temperature has increased only 1°C during the more than 10,000 years since the end of the last Ice Age.

An increase in the global average surface air temperature of such magnitude will bring about alarming changes in the pattern of rainfalls and other climate conditions, resulting in natural and ecological disequilibrium. One of the most conspicuous outcomes would be a rise in sea levels. A report issued by IPCC predicts that sea level will have risen 20 cm by 2030 and 45 cm by 2070. The rise in sea level of the order of 20–45 cm would have an almost catastrophic impact upon human life, since the majority of human settlements are located either near the seashore or by rivers. It is estimated that about half a billion people would be directly affected by the sea-level increase of such a magnitude. The strength and frequency of hurricanes and typhoons would also intensify, and the distribution of rainfalls would become more unstable. Climate changes accompanied by global warming would place particular hardships on farmers and fishermen, since the choice of crops and the mode of cultivation have been adjusted to suit climatic and soil conditions over many years and the availability of fish has been delicately correlated with the natural and ecological environment. The tropical or sub-tropical climate conditions would spread out further to the north (or to the south, for those in the southern hemisphere), thus disseminating the danger of tropical diseases and insects.

The principal causes of global warming we observe are atmospheric concentrations of radiative forcing agents, which keep infrared radiation from Earth's surface and warm the surface air temperature. The radiative forcing agents, occasionally referred to as "greenhouse gases", have now been identified as water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs).

A particularly important role is played by carbon dioxide. If carbon dioxide did not exist in the atmosphere, the global average surface air temperature would be around -20°C, thus making life on Earth impossible. On the other hand, an excess concentration of atmospheric carbon dioxide would warm the globe significantly. It is estimated that the planet Venus, which has a high atmospheric concentration of carbon dioxide, has a surface temperature of about 470°C.

The atmospheric concentration of carbon dioxide has increased from the level of 280 ppm (ppm = parts per million) at the time of the Industrial Revolution to the current level of 350 ppm. Most reliable measurements since 1958 have been made at Mauna Loa and the South Pole, indicating that the atmospheric concentration of carbon dioxide has increased at an annual rate of 1.3 ppm from 1959 to 1988, as compared with the annual rate of 0.3–0.5 ppm from 1880 to 1958. If the current trend were to persist, it would reach the level of 560 ppm by 2070, double the pre-industrial level, and the resulting equilibrium warming would be 2.5–4.5°C higher than the current level.

The atmospheric concentration of carbon dioxide is largely of anthropogenic origin, primarily caused by the burning of fossil fuels. The depletion of tropical rain forests also has become another major source of the atmospheric concentration of carbon dioxide in the last 30 years, now estimated to be responsible for one third of that emitted by the combustion of fossil fuels.

The mechanism by which the anthropogenic emissions of carbon dioxide disturb the atmospheric equilibrium may be best understood if we draw a crude picture concerning the global carbon cycles. There are three major reservoirs of carbon on Earth's surface, each roughly of the same capacity: the atmosphere, the surface ocean (to a depth of 75 m), and the terrestrial biosphere, respectively containing 700, 700 and 800 GtC of carbon (GtC refers to Giga = 10^9 tons of carbon). Land plants in "detritus" contain a much larger quantity of carbon, roughly of the magnitude of 3,000 GtC. The exchange of carbon between the atmosphere and the surface ocean is approximately in equilibrium, exchanging 90–

100 GtC. The terrestrial biosphere absorbs atmospheric carbon dioxide through the process of photosynthesis, at about 60 GtC annually. Roughly the same quantity of carbon dioxide is released to the atmosphere through the processes of decomposition and respiration. Thus the exchange of carbon between the atmosphere and the terrestrial biosphere is also in equilibrium. Prior to the Industrial Revolution, whatever the residual difference existed in the exchange of carbon between these three reservoirs had been delicately balanced by the eruption of volcanoes and other natural phenomena.

The stability of the global carbon cycle began to be disturbed by the massive consumption of fossil fuels, particularly of coal and oil, which characterised the new technologies brought about by the Industrial Revolution. The combustion of fossil fuels now emits 5–6 GtC of carbon dioxide annually. This has an important implication for the stability of the global carbon cycle. While the global carbon cycle on Earth's surface takes place within the time period of 10 to 100 years, fossil fuels are made of animals and plants which used to live on Earth's surface some 10 to several hundred million years ago and are being extracted at an extremely high pace.

Of the 5–6 GtC of carbon dioxide emitted by the combustion of fossil fuels, the largest contributor is United States (24%), followed by Soviet Union (20%), China (9%), and Japan (5%). These four countries, contribute two thirds of the world total. However, it should be borne in mind that the quantity of carbon dioxide emitted by the combustion of fossil fuels per GNP varies a great deal among the countries. The Japanese volume is roughly half of that for United States, suggesting a rather significant degree of substitutability for the energy use.

The stability of the global carbon cycle has been also disturbed by the massive depletion of land forests, particularly of tropical rain forests, in the last three decades. Total acreage of land forests is estimated at about 4 billion hectares, including open and closed forests and woodlands. According to an estimate made by the World Resources Institute, the acreage of tropical rain forests annually lost is now some 160–240 million hectares *(World Resources, 1990–91)*; a magnitude much larger than the previous estimate of 110 million hectares made by the FAO for 1980. It is estimated that 0.4–2.6 GtC of carbon dioxide are released into the atmosphere due to changes in the pattern of land use, about 95% of which are regarded as the result of deforestation of tropical rain forests.

Carbon dioxide is now estimated to be responsible for 55% of the greenhouse effect, while methane accounts for 15%, nitrous oxide for 6%, and CFCs for 24%. Among these greenhouse gases, CFCs are solely of anthropogenic origin, introduced for the first time during the 20th century. CFC-12 and CFC-11 are the most common CFCs with the atmospheric concentrations of respectively 484 and 280 ppt (ppt = parts per trillion). However, they have a powerful greenhouse effect, estimated to be 20,000 times more powerful than carbon dioxide. CFCs also tend to remain in the atmosphere for a long period of time, and are also responsible for the destruction of the ozone layer. In view of the imminent danger to which CFCs have exposed us, an international agreement was reached in 1987. The Montreal Protocol to Control Substances that Deplete the Ozone Layer stipulates a substantial reduction and the eventual abolishment of the production and use of CFCs.

Since the phenomenon of global warming has been scientifically established and has become one of the focal issues from economic, social, and political points of view, a number of international conferences and negotiations have been held by various governments and international agencies, some of which possess particularly important implications for arresting global warming. The governmental negotiations, however, mostly have the common trait that they try to agree upon a certain scheme whereby each country is obliged to curtail emissions of greenhouse gases to certain levels, typically as percentages of current emission levels, and try to implement their commitment through administrative or similar measures. Such an administrative scheme generally is difficult to implement within a decentralised, entrepreneurial framework, occasionally resulting in an inefficient allocation of scarce resources, particularly in terms of the provision of the incentive scheme for energy-saving technological innovations.

Imputed Prices and "Carbon Tax" System

The phenomenon of global warming is basically of anthropogenic origin, primarily due to the massive consumption of fossil fuels and secondly due to the depletion of tropical rain forests. The predominant forces behind these human activities are economic, and any policy or institutional measures to effectively arrest the process of atmospheric disequilibrium would have to take into account the economic and political implications such measures would entail.

There exist two distinctive features in the phenomenon of global warming which traditional economic theory is hardly equipped to deal with. First, global warming is related to the unstable concentrations of carbon dioxide and other greenhouse gases in the atmosphere. The atmosphere plays the role of social overhead capital, which is neither privately appropriated nor subject to transaction in the market. Traditional theory has been almost exclusively concerned with those scarce resources which are privately appropriated and whose ownership rights are transacted in the market. The second feature concerns with the equity problem between different generations or different countries. Those who emit most of carbon dioxide are those who benefit most from the combustion of fossil fuels, while those who suffer most from global warming are those who benefit least from the emission of carbon dioxide. By the same token, while the current generation enjoys a relatively high living standard due to the combustion of fossil fuels, future generations will suffer from global warming and other problems related to the atmospheric concentrations of carbon dioxide and other greenhouse gases. Again, traditional economic theory has shied away from problems involving equity and justice, restricting its realm to the efficiency aspect.

Thus the problem of global warming offers us a unique opportunity to re-examine theoretical premises of traditional economic theory and to search for a theoretical framework within which it is possible to handle the dynamic and equity problems involving environmental disruption. Such a framework will be provided by the theory of optimum economic growth and the theory of social overhead capital, both of which have been developed in the last two decades. In particular, the dynamic theory of environmental economics, as developed by Professor Karl-Göran Mäler of the Stockholm School of Economics, gives us the basic framework within which it is possible to analyse the economic and political circumstances under which global warming occurs and to find the policy and institutional arrangements to effectively arrest it. Mäler's theory is concerned with finding the pattern of intertemporal allocation of scarce resources in which the optimum balance between environmental quality and economic growth is attained, with the concept of imputation playing a central role.

The imputed price of atmospheric concentration of carbon dioxide at a particular moment in time expresses the extent of damage felt by the entire society due to a marginal increase in the level of atmospheric carbon dioxide. It takes into account not only the assessment by the present generation, but also it includes the assessment which future generations are inferred to make. The imputed price of atmospheric carbon dioxide is first used in obtaining from the static point of view. Namely, if a charge is levied for the emission of carbon dioxide evaluated at the imputed price, then the static efficiency is guaranteed, provided that markets for privately owned goods and services are perfectly competitive. Secondly, if the imputed price of atmospheric carbon dioxide is appropriately calculated, then the resulting pattern of resource allocation over time will approach the atmospheric level of carbon dioxide at which the optimum balance between global warming and economic growth is sustained.

Under certain qualifying assumptions concerning the welfare effect of global warming, it is possible to derive a simple formula for calculating the level of imputed price for atmospheric carbon dioxide. Let p be the imputed price of atmospheric carbon dioxide (at a certain moment in time t) and y be the per capita level of national income. Then,

$$\frac{p}{y} = \theta,$$

where the imputation coefficient θ is given by

$$\theta = \frac{\beta}{\delta + \mu} \cdot \frac{N}{\hat{V} - V},$$

where δ is the social rate of discount (usually 5%), μ is the rate at which the atmospheric level of carbon dioxide V in excess of the pre-industrial level is absorbed into the surface ocean (of the magnitude 4%), β is the intensity at which the effect of global warming is felt by the society, $\hat{V}$ is the critical level of atmospheric carbon dioxide, beyond which drastic changes in the environmental conditions brought about by global warming are feared to exert a serious and irrevocable damage on human life on the earth ($\hat{V}$ is assumed to be of the magnitude 1200 GtC), and N is the world population (N = 5.2 billion).

The imputed price for land forests may be similarly obtained. It expresses the extent to which the society evaluates the contribution the marginal increase in the acreage of land forests makes toward the decrease in the atmospheric level of carbon dioxide. If we denote by q the imputed price of a hectare of land forests, then the following formula may be simply obtained:

$$\frac{q}{y} = \eta,$$

where the imputation coefficient η for land forests may be expressed by

$$\eta = \frac{\gamma}{\delta} \theta,$$

Imputed figures for greenhouse gases

Country	Population 1991 (million)	Per capita national income (assumed)	Net annual atmospheric increase CO_2 (million tons)	Net annual atmospheric increase CH_4 (million tons)	Carbon equivalent	Net annual atmospheric increase CFC use (1,000 tons)	Carbon equivalent	Net annual atmospheric increase Total (million tons, carbon)	Net annual atmospheric increase Per capita (tons, C)	Imputed price ($/tC)	Assessment Total (million $)	Assessment Per capita ($)
United States	249	15,000	540	7.1	130	197	350.0	1,000	4.0	150.0	150,000	600.0
Canada	27	12,000	48	1.7	33	21	36.0	120	4.5	120.0	14,400	540.0
Indonesia	181	400	110	1.0	19	5	9.5	140	0.8	4.0	560	3.0
Japan	124	15,000	110	0.7	12	58	100.0	220	1.8	150.0	33,000	270.0
Korea, Rep.	44	2,600	21	0.2	29	3	54.0	29	0.7	26.0	754	18.0
Malaysia	17	1,800	22	0.1	1	1	2.5	26	1.5	18.0	468	27.0
Philippines	62	500	34	0.4	7	0	0.0	40	0.6	5.0	200	3.0
Singapore	3	7,000	3	0.0	0	2	3.7	7	2.4	70.0	490	168.0
Thailand	56	800	48	0.8	16	2	3.5	67	1.2	8.0	536	9.5
Australia	17	9,000	28	0.8	14	12	21.0	63	3.7	90.0	5,670	333.0
New Zealand	3	8,000	3	0.2	4	2	3.5	10	3.3	80.0	800	264.0

Sources: *World Resources, 1990–91*, Table 24.2, pp. 348–49, and others.

Imputed prices for reforestation

Country	Forests and woodlands (million ha)	Net annual reforestation (1,000 ha)	Imputed price (per ha)	Assessment Total (million $)	Assessment Per capita ($)
United States	300	1,600	15,000	24,000	96.4
Canada	436	720	12,000	8,640	320.0
Indonesia	120	-800	1,200	-960	-5.3
Japan	25	200	15,000	3,000	24.2
Korea, Rep.	5	80	2,600	210	4.7
Malaysia	20	-230	5,400	-1,242	-73.1
Philippines	10	-80	1,500	-120	-1.9
Singapore	x	x	x	x	x
Thailand	16	-370	2,400	-890	-15.9
Australia	110	60	9,000	540	31.8
New Zealand	10	40	8,000	320	106.7

Sources: *World Resources, 1990–91*, Table 19.1, pp. 292–93.

where γ is the amount of carbon dioxide annually absorbed by land forests per hectare ($\gamma = 5$ tC/ha/yr for temperate forests, and $\gamma = 15$ tC/ha/yr for tropical rain forests).

When we consider the situation where a number of countries are involved, the formulas for the imputed prices of carbon dioxide and land forests obtained above may be utilised, where the imputation coefficients θ and η are identical for all countries involved. Thus, if we assume that the society is extremely insensitive to the problem of global warming, say $\beta = 0.1$, then the imputation coefficients are given by

$$\theta = 0.01, \ \eta = 1.0 \text{ or } 3.0.$$

Then the hypothetical values for imputed prices may be obtained like this: The imputed price of carbon dioxide is $150 for the United States and Japan, while it is $4.0 for Indonesia and $5.0 for the Philippines. The carbon taxes on the per capita basis will be $600 for the United States, $270 for Japan, $3.0 for both Indonesia and the Philippines. As for land forests, the imputed price per hectare of land forests is $15,000 for both the United States and Japan, $1,200 for Indonesia, and $1,500 for the Philippines.

Similar calculation may be made for other greenhouse gases. One may simply take into account the relative effect upon global warming and the rate at which each greenhouse gas is absorbed into the surface ocean.

As for the administrative framework through which the carbon tax system may be implemented, one may refer to the experience the Japanese Environmental Protection Agency had concerning sulphur oxide.

International Fund for Atmospheric Stabilisation

The carbon tax system introduced above is based upon the concept of imputed prices, where not only is the efficiency of the allocative mechanism taken into consideration, but also it is designed in such a manner that the equity problem will be solved in the long run. The difference in the economic conditions between developed and developing countries, however, has been so extensive in recent years that the introduction of such a carbon tax system alone will not suffice to reduce it. It would be desirable, therefore, to introduce institutional arrangements in which the carbon tax system is supplemented by the international redistributive scheme. Such arrangements would be provided, e.g. by an International Fund for Atmospheric Stabilisation. A certain portion of the net receipts each national government collects through the carbon tax system will be transferred to the International Fund for Atmospheric Stabilisation, which, in turn, would allocate the total revenues to developing countries in the pro rata basis according to the per capita level of national income and the population size. Developing countries then may use the amounts transferred from IFAS for whatever purposes they find desirable, primarily for compensating the hardships incurred by the carbon tax system and for introducing substitutional energy sources and energy saving-technologies.

Whether such institutional arrangements may be effectively implemented depends upon the degree of consciousness concerning global warming possessed by the general public and national governments in concern and upon the extent of willingness of the international community to preserve the delicate stabilising mechanism of our planet.

Science, Society and Values

Chair : Erik Haites

Rapporteur: Ann Heidenreich

A Conceptual Map of Human Values for Climate Change Decision Making

STEVE RAYNER*
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Introduction—The Need for a Map of Human Values

I have been asked today to address the issue of values in science and societal decision making. I am pleased to do so because the issue of values lies at the heart of debates about climate change, even though the debates are most often couched in scientific terms. In other words, debates about climate change are what Weinberg (1972) called *transcientific* debates in which questions are framed by science, but cannot be answered by science alone. Essentially, while science considers the puzzles of climate change, such as where is the missing sink in the carbon cycle, it cannot resolve the essential human problems, such as how many more poor people in vulnerable developing countries are we prepared to see go hungry, get sick, and die young than we presently tolerate.

Figure 1, drawn from the field of risk analysis, graphically illustrates this situation by situating the climate change issue high on orthogonal dimensions of *scientific uncertainty* and *societal decision stakes. Uncertainty* here includes the elements of inexactness, uncertainty, and ignorance surrounding the precision of estimates and measurements, adequacy of methods, and appropriateness of concepts involved in technical studies. Decision stakes contains not merely the technical assessments of benefits and costs but judgments about what is fair and even the societal determination of what is valued. Where both uncertainties and stakes are low, decision making is characterised by routine procedures and application of formal decision rules to well-known data. Where either uncertainties or stakes rise, decision making relies much more heavily on the interpretive and anticipatory craft skills of scientific and political practitioners. Where either uncertainties or stakes are high, decision making is almost entirely dominated by the competing world views of the people involved and is likely to be conducted in an adversarial mode. Although elements of the climate issue may be close to the origin in this picture, the societal issue as a whole remains in the top right-hand corner.

The IPCC process has quite properly focused on the reduction of scientific uncertainty in the hope of shifting the climate change debate from an arena of deep social conflict towards the routinised implementation of consensual goals. However, Fig. 1 shows that reduction of scientific uncertainty alone will never permit the reframing of climate change in this way unless attention is also paid simultaneously to reducing the decision stakes. While impact assessment attempts to improve our understanding of the decision stakes, it does not, of itself, adequately describe what people value nor does it address issues of fairness in the distribution of impacts. However, it is only by simultaneously reducing the decision stakes that the climate change issue can be made more tractable. Because decision stakes represent the potential losses and gains of what people value, and because human values diverge in important ways, an inquiry to establish the global landscape of human values is a prerequisite to any successful policy strategy for climate change.

I am not advocating that we all become experts in the abstract systems of moral philosophy or comparative theology. On the contrary, I shall argue below that these disciplines can provide only very limited practical insight into the dynamics of competing value systems, precisely because of their abstraction from social action. But, a practical understanding of the diversity of human values, how different value systems arise and are maintained, and the social, economic, political, and even spiritual dynamics that occur when diverse value systems interact with each other, would seem to be essential for any researcher or policy maker seeking to understand and intervene in debates about human actions and climate change. One would think that a practical map of the global landscape of values would be as valuable as a model of greenhouse gas emissions and atmospheric

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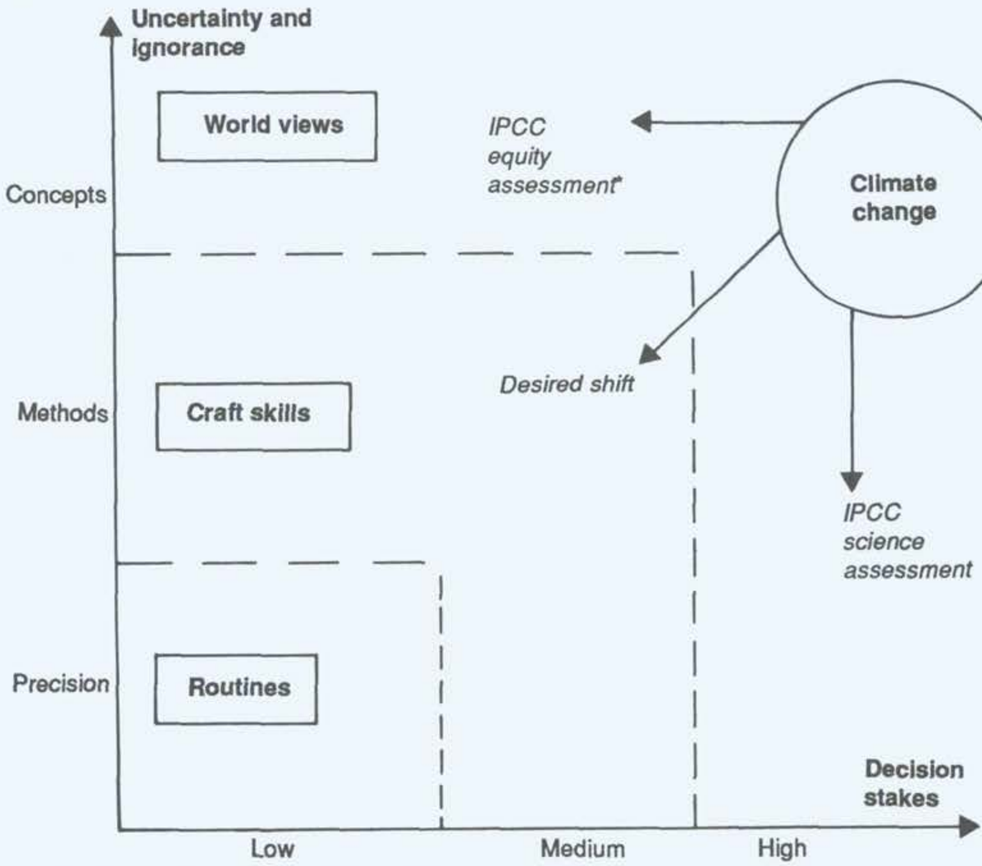
chemistry, or climate change and ecosystem impacts. Yet, while we are, quite properly, spending millions of dollars improving our scientific tools, we seem willing to negotiate the socio-economic, political, and ethical landscape with a deeply impoverished, even one-dimensional, picture of equity.

By one-dimensional picture I mean that we assume all human beings share the same basic motivations and procedural preferences, and will respond in the same way to the same incentives. These assumptions are unquestioningly adopted throughout the deliberations of Working Group III as the basis of formal prescriptive systems for determining international negotiation of emissions reduction targets or the choice of policy implementation instruments designed to help nations meet such targets (IPCC, 1994). If these assumptions about the homogeneity of human behaviour were true, the problem of equity in climate change policy would be relatively straightforward and the search for a singular prescriptive solution would be plausible. Unfortunately, a century and a half of social theory and the descriptive study of practical ethics (by which I mean studies of people's actual ethical behaviour rather than abstract development of formal systems describing what people ought to do) suggests that this one-dimensional picture is not merely an innocuous methodological simplification, but may be false in important and relevant ways.

For example, while international debates about emissions rights clearly reflect national and regional self interests, it can also be shown that they represent competing principles of distributional justice, different notions of entitlement, different concepts of procedural fairness, asymmetries in preferences for international and intranational equity, clashing concepts of human obligations to other species, etc.

If the real issue facing policy makers is not the design of a single efficient distribution but, rather, how to negotiate among competing, possibly incompatible, claims about what is fair, then we are in dire need of a parsimonious formal system for comparing and evaluating competing claims on resources. Hence, I shall attempt in this paper, not only to identify the shortcomings of the one-dimensional view of equity, but also to sketch out the contours of the moral landscape as the social sciences find it in the real world. This is only the first step towards supplying a map of values as they affect practical debates about equity and climate change, which has yet to be developed. In this way I hope to demonstrate that a much expanded discourse, recognising a far richer repertoire of procedural options and preferences for outcomes, is a prerequisite for the analysis and formulation of climate change policies both among and within nation states.



*This component is currently underdeveloped.

Fig. 1. Framing climate change in terms of uncertainty and values (adapted from Funtowicz and Ravetz, 1985).

One-Dimensional Concepts of Equity

I describe the discussion to date as one-dimensional for a number of reasons. First, the discussion equates equity solely with distributional outcome at the expense of the role of procedural justice. Yet, for many actors procedural equity is, in theory and practice, a higher moral and psychic good than a preferred distribution. We are all familiar with the satisfaction of a preferred result fairly obtained, our capacity for stoicism in the face of an undesired result that we nevertheless consider to be fairly obtained, our lingering sense of guilt about a preferred result unfairly obtained and our outrage against an undesired result unfairly inflicted upon us (Table 1).

Table 1. Common responses for interactions of process fairness and outcome fairness

	Outcome	
Process	Fair	Unfair
Fair	Satisfaction	Stoicism
Unfair	Guilt	Outrage

Where procedural equity is considered in our present discussions, it is confined to an ethnocentric principle derived from Anglo-Saxon law that similar cases and similarly situated claimants should be treated in a similar fashion. This conception of procedural fairness in law is part of a tradition of *universalism,* defined by Bennett and Dahlberg (1990, p. 72) as "a way of generalising the applicability of institutions to all classes of people regardless of contextual particularities". The principles of procedural equity in African traditional law have quite a different *contextualist* focus, seeking instead to elaborate the unique features of cases and claimants and their place in the community. Standardisation of procedure and mandatory fixed penalties represent a denial of justice in this kind of system (Comaroff and Roberts, 1981). Although some commentators detect a global historical trend in the direction of universalism, others would contest this. Almost all would agree, however, that despite the *universalist* claims made for various procedural ethics, there remains considerable variety in people's preferences for procedural fairness. Since one of the roles of the IPCC assessment is to inform negotiators, it seems appropriate to supplement their existing practitioner craft skills by providing them with the best insights of the social sciences into the variety of procedural preferences that they are likely to encounter on the global stage.

Second, the discussion that we have been having reduces distributional fairness to Pareto optimality. The notion that a fair outcome must not leave any party worse off than before is a highly technical concept of justice derived from the prescriptive value placed on efficiency in theoretical economics (Rose, 1990). In practical ethics, based on what people actually do when trying to find fair and agreeable solutions to everyday problems, Pareto optimality is rarely sought and hardly, if ever achieved. For example, if Pareto efficient solutions were consistently and universally valued, no-one would ever lay down his or her life for family, faith, or fatherland. That people do is not a failure of practical ethics but, rather, a recognition of other principles and considerations to which people give more weight. Since the IPCC assessment seeks to advise policy makers on the issue of implementation and selection of policy instruments, knowledge of people's actual criteria for judging the fairness of an outcome would seem helpful.

Third, we tend to uncritically accept the enlightenment doctrine that ethical rules, like scientific laws, are *universal.* Those who question this doctrine are liable to find themselves (as I have experienced) condemned as *post-modern* relativists, for whom any proposition is as good as another. We are told that to question universalism (the existence of a single truth) is to eliminate the rational basis for choosing among rival theories (which one brings us nearer to that truth?). According to this view, to abandon *universalism* is to eliminate the prospect of improving knowledge and of effective social action. However, it is actually universalism that eliminates the possibility of making sound choices among rival moral principles. In fact, as one initially trained in philosophy and theology, I experienced considerable frustration at the presentation of diverse ethical theories like goods on a supermarket shelf. We can read the ingredients, note the method of preparation, and try to recall if we enjoyed other products from the same manufacturer (Perhaps his theory of knowledge appealed to us last semester?). But here we are only reproducing previous consumption choices. We can apply formal logic to uncover internal inconsistencies or to nitpick about peculiarly knotty dilemmas that consistent application of the axioms create. But, since all of the theories are susceptible to this sort of criticism (Young, 1993), logic actually provides no clue as to how to choose among rival candidates for universality.

Other than subjective individual taste, there is no way to pick and choose among rival moral theories until we begin to apply their principles to see how they affect human relations in real societies. Once we do that, we have some objective criteria to choose among theories, that is, their compatibility with preferred modes of maintaining social solidarity or kinds of social bonding. Does a principle disrupt or erode a particular kind of solidarity or strengthen it? However, in adopting such objective criteria for choosing among ethical theories we are forced to abandon universalism because societies and institutions demonstrate considerable diversity in the organisation of human relationships which they use to create and maintain social solidarity. This diversity is not usefully reducible to a single utility function, which merely masks the basis of ethical disagreement. Appreciating that diverse ethical preferences are both real and deeply rooted in social life is not post-modern self-indulgence, but a practical necessity for understanding why certain technologies are easily adopted in some settings but rejected in others (Schwarz and Thompson, 1990).

Fourth, *universalism* is the basis of various theories of basic needs. However in practice the establishment of universal basic needs has proven so elusive as to render the concept highly questionable. Individual calorific requirements depend on age, climate, and level of activity, apart from any physiological variation among populations. Admittedly everybody needs to breathe, but what level of air quality can be said to meet basic needs? Most of us probably agree that everyone should have access to potable water, but how clean must water be to be considered potable? Given the number of people in this meeting hall who are buying bottled water rather than drinking the plentiful supplies of slightly cloudy but quite tasty city water provided *gratis* by the organisers, these issues are not distant abstractions.

Fifth, as a consequence of *universalism* the discussion of equity that we have been having is highly prescriptive. It attempts to enunciate the correct approach that all decision makers should agree to adopt in pursuit of a fair solution. However, once we reject *universalism* and realise that ethical preferences are deeply rooted in forms of social solidarity and the organisation of social, economic, and political institutions, we recognise that the prescriptive challenge is not likely to be met by discovering a single distributional principle that all will agree on. It is more likely to be met by designing a process that is able to engage and retain the participation of parties upholding incommensurable preferences (Gerlach and Rayner, 1988; Schwarz and Thompson, 1990; Rayner, 1992). If this insight is justified then it could make a significant difference to the conduct and analysis of international negotiations away from optimising outcomes towards optimising processes. Given the high scientific uncertainties surrounding outcomes anyway, such a shift may be doubly desirable.

My final difficulty with our discussion of equity thus far is that it atomises transactions and transactors both spatially and temporally. The focus on distributional outcomes leads us to a static or, at best, a serial view of individual transactions subject to one-shot solutions, i.e., a particular Pareto-optimal distribution among current players. We are losing sight of the fact that those transactions take place within complex interlocking webs of social solidarities that create continuing expectations of obligation and entitlement. In the real world, transactions are interdependent. In fact, as Marcel Mauss observed in his classic work on *The Gift*, the maintenance of social relations may depend very largely on keeping a running balance of unfairness in transactions because the obligation this creates for future reciprocity is actually the glue that holds human societies together (Mauss, 1925). Interestingly, modern analysts of informal economies recognise the centrality of maintaining social bonds in intimate trading networks and markets for stolen goods, while analysts of formal markets ignore this dimension of trading and exchange relationships altogether (Cantor et al., 1992). This is partially an outcome of the commitment of formal economics to methodological individualism, which assumes a rational individual transactor maximising his or her own expected utility from each transaction. Again, this is not a mere theoretical quibble because methodological individualism is particularly poor at handling intergenerational issues that are central to achieving equitable resolutions of the climate issue. Individuals die, and their motivations die with them. However, families, corporations, and nation states are institutions and may be better understood in terms of how they create solidarity within and across generations.

In contrast to the one-dimensional approach, I will be descriptive, not prescriptive. Rather than attempt to discover what ought to be the ethical principles used in negotiation and policy implementation about climate change, I shall describe a set of diverse principles that people actually do use in debates about risk and fairness. I shall do this in the most parsimonious terms possible that preserve the commitment to understanding ethical pluralism. I shall demonstrate how different concepts of equity are rooted in contrasting modes of establishing and maintaining social solidarity across the entire social scale from families to the community of nation states. I shall argue that the ways we bind ourselves to each other also shape the ways in which we bind ourself to nature and hence whether we are likely to support *anthropocentric* or *naturalistic* ethics. Because societal ethics can only be evaluated within an institutional framework that is extensive in time and space, and not as individual transactions, I shall focus on institutional *preferences for both distributional outcomes and* procedural fairness.

Equity and Social Solidarity

What is fair may be the subject of disagreement, but the demand for fairness only arises because of the existence of community. It is very hard to imagine what fairness would mean if we did not live and work together in families, communities, firms, nations, and other social arrangements which persist over time. The whole issue of fairness arises out of the establishment of public, i.e. shared, expectations for the conduct of community relations (*procedural* equity) and the distribution of rights over resources within and among communities (*distributional* equity). In other words, fairness is integral to the establishment and maintenance of social solidarity at every level of social institutions from the micro to the macro; from the local to the global. Protest and defection from institutions result when public expectations for procedures or for the outcomes of allocations are repeatedly violated or people cannot be persuaded to embrace emergent alternatives (Hirschman, 1970). Family members may argue or leave home. Where reform fails people switch religious denominations or give up church altogether. If scientists' letters to scholarly journals fall on deaf ears they may cancel their subscriptions to professional societies. Disgruntled employees walk off the job singly or *en masse*.

Attention to fairness as procedure and outcome is the maintenance of social solidarity. More than 150 years of social theory spanning legal history, sociology, anthropology, psychology, economics, and political science indicates that social solidarity can be built in many ways and across different scales from families to federations of nation states.

However, my promise of parsimony requires that we reduce this rich diversity to the minimum number of basic modes or patterns of solidarity that can be distinguished usefully. It would also be advantageous if we could devise a basis for distinction that would hold across the board from micro to macro scales of social organisation. I have already argued that one pattern of solidarity or principle of fairness is too few, but why not two?

Dichotomous distinctions have proven to be very durable in the history of social theory. In the mid 19th century, the legal historian Sir Henry Maine (1861) distinguished social solidarity based on *status*, in which actors know their place in hierarchical structures based on the idiom of the family, from solidarity based on *contract* in which agents freely associate by negotiated agreement. Later in the century, German sociologist Ferdinand Toennies (1887) distinguished between *gemeinschaft*, where societies are bound by ties of kinship, friendship, and local tradition, from *geselleschaft* where social bonds were created by individualist competition and contract. At the turn of the century French anthropologist Emile Durkheim (1893) distinguished human societies based on *mechanical solidarity* in which agents bind themselves to others on the basis of sameness, from those built upon *organic solidarity* in which agents are bound together by the interdependence of specialised social roles. Each of these grand dichotomies was viewed by its author in evolutionary terms which continue to resonate in contemporary social theorising, such as that of Bennett and Dahlberg (1990) who, echoing Durkheim, detect in the development from preindustrial to industrial society, a shift from *multifunctionalism*, where everyone can do everything, towards *specialisation*. For the most part, however, more recent approaches dispense with the unidirectional evolutionary assumption. Educational psychologists have identified *positional* families in which behaviour is regulated by appeals to hierarchical authority and *personal* families in which behaviour is regulated by appeals based on individual preferences (Bernstein, 1971). Major contemporary political scientists and economists such as Charles Lindblom (1977) and Oliver Williamson (1975) focus on the different characteristics and dynamics of coexisting and competing social systems based on the social bonds created through participation in *markets* and those based on the solidarity of *hierarchy*.

There is a great deal of overlap among these grand dichotomies of social theory. However, they are far from perfectly congruent and, in sum, give rise to three, rather than two basic forms of social solidarity (Table 2).

First, solidarity can be expressed through the *market*, characterised by the features of individualism and competition associated with *geselleschaft*. Solidarity is achieved in two ways, most obviously through *contracts*, but also through individual consumption choices that establish identity with fellow consumers and differentiation

Table 2. Characteristics of three kinds of social solidarity as described in classic social science literature

Market	Hierarchical	Egalitarian
Gesselleschaft	*Gemeinschaft*	*Gemeinschaft*
Organic solidarity	Organic solidarity	Mechanical solidarity
Specialised roles	Specialised roles	Multifunctional roles
Personal authority	Positional authority	Personal authority
Contract relations	Status relations	Status relations

from those who follow different consumption patterns. As manifestations of *geselleschaft,* market forms of solidarity are directly orthogonal to both of the other basic modes of solidarity, described below, which share the stronger community boundaries typical of *gemeinschaft* solidarity.

Second, solidarity can be expressed through orderly differentiation in *hierarchies,* the rules for which establish identity through careful gradations of *status* based on explicit characteristics such as age, gender, educational attainment, professorial rank, etc. This form of *positional* authority is directly orthogonal to the emphasis on *personal* freedom shared by both markets and the third form of social solidarity.

Third, solidarity can be expressed through *egalitarian* homogeneity; that is by operating rules of equality that keep each participant at the same *status.* In this respect, egalitarianism is a manifestation of *mechanical* solidarity and *multifunctional* roles that is directly orthogonal to both hierarchies and markets which both favour *organic specialisation* of labour.

This synthesis creates a two dimensional space within which multiple possibilities for institutions can be located (Fig. 2). This has several methodological and pragmatic advantages over dichotomous frameworks.

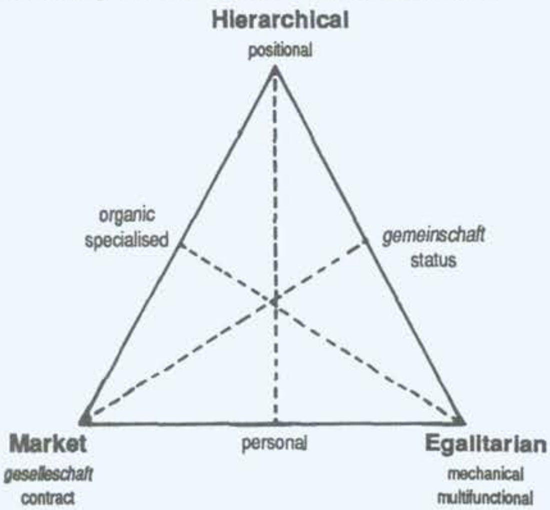


Fig. 2. Two dimensional map of kinds of social solidarity underlying human values preferences.

Methodologically, it is satisfying because it systematically encompasses the spectrum of dichotomous distinctions that have informed a century and a half of a wide range of empirical social sciences. This inclusiveness suggests that the three basic types are fairly robust.

The endogenous dynamic qualities of the two-dimensional framework are also methodologically appealing. Each kind of solidarity only exists in distinction from the other two, therefore, instability and conflict is inherent to the framework, as it is in real life, and does not require the action of an exogenous agent for changes in social organisation or the values that support it. The potential for endogenising social change may have important implications for long-term policy modelling which presently is unable to deal well with changes in societal preference functions such as the demographic transition.

The dynamic quality of the triangular space contrasts with evolutionary dichotomies which are like a pipe with a non-return valve that permits fluid to flow in only one direction. The unidirectional flow metaphor may be an appropriate one for the history of pollution entering the environment, but it will not do for social development. Merely dispensing with the evolutionary assumptions associated with dichotomous schemes still leaves us with an overly simple switching model in which only two states are possible. If the system is not in state A it must be in state B, and *vice versa.* By contrast, the triangular system is a complex framework, in that not being in state A does not automatically imply state B. It is therefore a non-deterministic framework.

However, much more important for the current focus of the IPCC, this framework explicitly focuses on modes by which people bind themselves to each other in social institutions and, in so doing, they:

- define their own basic needs,
- develop preferences for distributional equity,
- establish principles of procedural fairness,
- establish principles for intergenerational equity, and
- shape their epistemological and moral relationship with nature.

I shall discuss each of these in turn.

Consumption and Basic Needs

People bind themselves to each other through acts of production and consumption. The creation of social bonds through cooperation and competition is self evident in the process of production. As best we can reconstruct the evolution of early human societies, the first form of social organisation was that based on the basic reproductive unit engaged in subsistence foraging. The key innovation that permitted the development to hunter-gatherer bands seems to have been a superior method of group hunting (Bennett and Dahlberg, 1990). The evolution of new institutions of social solidarity is often closely associated with the organisation of production such as family farms, craft guilds, and industrial firms.

However, the goal of production is to satisfy consumption which can be viewed as the final act in the productive process. Consumption itself is an essential means of creating social solidarity and the way consumption is organised is a powerful expression of social order (Douglas and Isherwood, 1978). It is easy to see how special holiday feasts in North America and Europe bind members of the extended family who may be separated throughout most of the year. What may be less obvious is that the everyday patterns of eating within the household bind family members on a daily basis (Douglas, 1984). Do household members dip into the larder at will and prepare separate snacks reflecting their individual culinary preferences and their independent social schedules (as in an individualist market household), or do all household members eat all of their meals together at the same table at set times (as in a hierarchical or egalitarian household)? Hierarchical dinners can be distinguished from egalitarian by the presence of fixed seating arrangements, the allocation of choice items, and different sized portions based on gender and seniority.

Creating social bonds through consumption in the market mode is intimately tied to differentiation and affiliation through individual consumer choices—the operation of consumer sovereignty. However, the consumer does not choose between Pepsi and Coke simply because of subtle flavour differences, but also because he or she wants to identify with Pepsi people and distinguish him or herself from Coke people, or vice versa. This way of conducting social relations leads to proliferation of subtly differentiated products and services that provide the consuming individual with an ever widening range of possibilities to make and break relationships with other participants in the market (Sack, 1990). This tendency often attracts criticism from egalitarian advocates of voluntary frugality as "mindless consumerism". However, consumption cannot be mindless in this kind of institution. It is an expression of the market consumer's most basic need of all, that of establishing his or her individual identity in relation to others.

Claims about needs arising in the individualist market setting tend to emphasise specific individual rights such as freedom of choice, freedom of expression, and individual opportunity for personal growth and development. Actions or policies, such as regulations or taxes on consumption at a level that would constrain fulfillment of these needs are rejected as fundamentally inequitable. The notion that standardised levels of consumption can be established as basic are difficult to comprehend, even offensive, in the market individualist setting. For what level of activity should we set minimum calorific intake? Is there not a wide range of individual variation in the hours of sleep we each require. Whether or not shoes are a basic need may depend on where you stand!

By way of contrast, hierarchical solidarity is based on institutional allocation according to rank or station. Consumption is a social marker, but the institution, rather than the individual, is sovereign. Here, consumption of appropriate goods, in the right quantities for the occasion and one's social station, is the means of establishing and maintaining solidarity. To consume habitually at a level above what is prescribed for one's place in the social order is likely to result in sanctions for acting above oneself. Similarly, to consume habitually at a lower level, or to fail to rise to the occasion for special events, such as weddings or coronations, is likely to attract opprobrium for falling below one's station (Dake and Thompson, 1993). Hierarchies, therefore, require a sufficient variety of goods to maintain distinctions in the social order, but this variety may be smaller and much lumpier than that necessary for the market.

Claims about basic needs in the hierarchical setting are dominated by the needs of the institution. Such claims emphasise collective security and stability within the existing order. In times of crisis, individual members of the institution are expected to make sacrifices at different levels. A CEO may give up his wood panelled office, a mid-level executive his company car, and a production-line worker a significant part of his weekly paycheck through loss of overtime or whatever. Basic needs are, therefore, viewed as variable according to one's station and responsibilities. Resources are allocated on the basis of differential assessments of needs. Unlike in the market setting, attempts to set standardised levels of minimum consumption are accepted as fair, provided that they are sensitive to customary status differentials.

The egalitarian setting differs from both the market individualist and the hierarchical setting in that it does not require product differentiation. In fact, an important means of establishing egalitarian solidarity is creating homogeneous consumption. Rules governing the width of hatbands and constraining other manifestations of conspicuous consumption are critical to the maintenance of Amish communities in North America (Hostetler, 1963), just as community norms prescribing consumption of beer, rather than whisky, and limiting the purchase of motor cars to a modest range of models was essential in maintaining the social solidarity of English mining communities (Dennis et al., 1969).

Egalitarian claims about needs are framed on a *per capita* basis, while voluntary frugality is positively valued. The important thing is that everybody has the same, or as close to the same as can be achieved. Of course, egalitarians claim that egalitarianism is a response to scarcity of resources, but neither the historical nor the contemporary ethnographic record indicates that there is any strong connection between scarcity and demands for equality (Flanagan and Rayner,

Table 3. Basic needs as framed within three kinds of social solidarity

Market	Hierarchical	Egalitarian
Choice	Security	Cohesion
Growth	Stability	Uniformity
Plethora of goods	Lumpy choice of goods	Undifferentiated goods

1988). Violations of the strict equality principle actually threaten the existence of institutions and societies based on mechanical solidarity, hence any tendency towards competition in consumption is seen as undermining efforts to ensure that there is enough to go around. In this setting, the concept of uniform needs is the basis for arguing that there are universal entitlements that conform to the egalitarian concept of fairness. These needs/entitlements are invariably set at a slightly higher level than that currently attained by the many who are currently below the median level of consumption, but considerably lower than the level currently enjoyed by those at the top of the consumption scale.

In summarising these insights into the concept of basic needs (Table 3), one is forced to conclude that the concept is highly problematic in practice. Social solidarity is itself a basic human need that can be satisfied in a number of ways. The way in which we satisfy that need may well be the decisive factor shaping the ways in which we satisfy other needs. We are all able to resonate positively to the broadly defined idea that there are basic needs, but we disagree about what they are and what level of satisfaction is *basic*. If the IPCC were to attempt a technical exercise to actually establish levels of basic needs, we would see a lively and highly contested debate that is not just based in technical uncertainty about the size of minimum daily calorific intake, or how clean is clean water and how accessible must it be to satisfy basic criteria for access, but also on different rankings of strongly held values. In this light, proposed distinctions between so called *survival emissions* and *luxury emissions* become questionable (Agarwal and Narain, 1991).

Distributional Equity

Our discussion of basic needs brings us naturally to the issue of distributional justice. In this section I shall confine myself entirely to the issue of preferences for outcomes.

Three principles that can be applied to resolve practical problems of making fair allocations of resources emerge from the work of mathematician Peyton Young (1993). These are *proportionality*, *priority*, and *parity*. However, I shall use these terms slightly differently from Young's usage to examine alternative proposals for allocating emissions rights.

Young uses *proportionality* to describe the Aristotelian principle of allocating benefits according to contribution. He distinguishes this from *priority* which is allocation based on the strongest claim, for example, need in the case of kidney transplants or seniority in avoiding job layoffs. However, it seems that contribution, seniority, and need are all bases for claims that are intended to be settled by administrative allocations made by an adjudicating authority. I shall, therefore, use *proportionality* to indicate a distributive outcome where benefits are allocated in accordance with an administrative determination of rank, contribution, or need. For example, the allocation of the kill in hunting groups usually follows a hybrid of all three criteria, specific parts of the prey being allocated to specific relatives or tribal elders, other cuts go to hunters according to specific roles they played in the hunt, and others to those who may have a specific need (Coon, 1987). According to this definition, the principle of proportionality is clearly compatible with the maintenance of hierarchical solidarity.

This usage frees the term *priority* to be applied to distributional outcomes that are achieved through successful competition, in other words, first-in-time; first-in-right. This principle is well established in frontier conditions and today remains the basis of water law in the western United States. It is also a principle enshrined in the patent system, first introduced in England in 1623 (Headrick, 1990). Patents are the origin of intellectual property rights designed to concentrate the benefits of innovation on the inventor so as to stimulate and reward intellectual competition. The overall societal benefits of that increased competition are supposed to include greater volume and velocity of technological innovation and incentives for wider dissemination of innovation through benefits of scale in production. Defined thus, the priority principal is clearly compatible with market individualist solidarity.

The third principle of distribution is *parity*. This can be understood as the principle of equal shares to all claimants. This is relatively simple to apply on an individualistic basis to divisible goods. However, with goods that are harder to divide, parity leads towards the creation and maintenance of common property systems. Clearly, parity is most compatible with egalitarian solidarity. It is also the basis of the principle for allocation of emissions rights that has been passed unchallenged at this workshop—that each inhabitant of the earth has the right to an equal use of the atmosphere. Hence, a fair allocation of emission rights to nation states would be one based on *per capita* population.

This argument has been most steadfastly articulated by the nations of the South. Yet, within those nations, *per capita* parity is seldom, if ever, the operational distributional principle. Brazil's economy resembles Spain's in every important respect save the distribution of wealth. India has a middle class larger than the entire population of many northern countries, although a recent estimate in the *Washington Post* of 240 million clearly includes many people we would have difficulty in recognising as middle class. However, MTV is piped into more than 3.5 million Indian homes. Assuming these homes contain 4.5 people—probably the average Northern household—Indian MTV is reaching a population (15.7 million) larger than the total population of many Northern nations. However, MTV reaches only 17% of Indian cable subscribers. If we were to make the conservative assumptions that the affluent middle class is only twice the size of the MTV audience (say 31 million) and is as energy efficient as the average Japanese citizen (2.5 tC/capita/annum), the CO_2 emissions of the Indian middle class alone would exceed the total emissions of Australia—one of the industrial villains who would be required to cut industrial consumption by factors of 10–20 within a few decades.

From this standpoint, it seems that the vast numbers close to destitution rescue the middle classes of many developing countries from the same accusations of *per capita* over consumption that they themselves level at northern countries. Furthermore, although far from equal, the actual distribution of wealth within the nations of the North is far closer to the per capita average than in the nations of the South. Hence, from a Northern perspective, claims based on the *parity* principle that the North has a moral responsibility to take the lead in cutting consumption may not be compelling. The so-called *survival emissions* of poorer countries may, in practice, translate into the *luxury emissions* of their elites. Claims that international equity should be established on the parity principle would be more compelling if mechanisms were established to ensure that, for example, a carbon tax does not simply reduce the welfare of the poor in the North, to benefit wealthy elites in the South. However, such mechanisms are likely to be viewed by those elites as unacceptable violations of national sovereignty.

Furthermore, *parity* is by no means the only basis which has been advanced in the argument. In fact, advocates of market solidarity, mostly in the North, have invoked the priority principle to argue that, far from incurring a debt to the South by its historic carbon emissions, the North was merely exercising its right of first-in-time. It is also argued, by analogy with the case that patent rights result in increased general welfare through concentration of initial benefits, that the industrial development of the North has resulted in a global increase in welfare. Hence, a fair allocation of emission rights would be one that recognises the historical dependence of the industrialised countries on fossil fuels and would allocate emissions rights to nation states on the basis of GDP. Clearly, this approach violates the *parity* principle of egalitarian solidarity.

The third proposal is typically *proportional* in that it seeks to devise a formula that recognises the egalitarian claim to parity as one based on need and recognises the priority claims of market-based solidarity as claims of contribution and seniority. Such a formula would seek to combine population and GDP to provide a fair distribution of emissions rights for each nation state.

This example also illustrates that the hierarchical kind of solidarity, because it is driven by the imperative of maintaining system stability rather than by promoting growth or equality, is the only one of the three that does not prefer clearly asymmetrical principles for losses and gains. Hierarchical institutions tend to favour deep pocket solutions as fair mechanisms for distributing liabilities (Calabrese, 1970). In this way hierarchies make use of redistributive mechanisms, such as taxation, to apportion liabilities in a way that seems to them to be least disruptive, not to the whole society perhaps, but certainly to those constituencies whose stability they see as important to the survival of the institution. Just as hierarchical institutions prefer to transfer losses through the system, they symmetrically prefer a system of allocating benefits where they best reinforce the accepted structures. Hence, hierarchies tend to favour *utilitarian* formulations of equity.

Policy makers in market individualist settings tend to favour *loss-spreading* in which market systems such as insurance and reinsurance determine who bears losses (Calabrese, 1970). When pure market solutions are not available, institutions of this sort attempt to reproduce what the market would have done if it had not been impeded by high information and/or transaction costs. For example, the Price-Anderson Act was designed to limit the liability carried by nuclear plant operators in the US in favour of diverting the costs to the population in general. This is asymmetrical to the principle that allows the individual risk initiator to collect any gains that may accrue.

Members of egalitarian groups seek a moral determination of liability that appeals directly to egalitarian values. This is a strict-fault system

Table 4. Outcome fairness and asymmetry of losses and gains according to three kinds of solidarity			
	Market	Hierarchical	Egalitarian
Principle for gains	Priority	Proportionality	Parity
Principle for losses	Loss spreading	Deep pocket	Strict fault
Outcome for gains	Narrowest	Greatest good	Broadest
Outcome for losses	Broadest	Least harm	Narrowest

(Calabrese, 1970) that makes those who are seen as responsible for imposing the risk directly responsible for the costs. By this means, egalitarians aim to eliminate incentives to cut corners on safety, or even to continue with the activity at all. The strong preferences of egalitarian institutions for allocating costs to guilty parties is asymmetrical to their communal principle of the broadest spread of gains. Thus the argument in favour of parity in the distribution of emissions rights goes hand-in-hand with argument that the North should bear the costs of climate change policies because it is responsible for the bulk of historical greenhouse gas emissions. However, this argument raises fundamental issues about principles of procedural fairness. These preferences for distributional outcomes are summarised in Table 4.

Procedural Fairness

There are many approaches to the issue of procedural fairness. One that has been used quite effectively in the analysis of societal responses to technological hazards is that which focuses on preferred procedures for obtaining consent to risk (MacLean, 1980; Rayner and Cantor, 1987). Institutional preferences for valid principles of consent are summarised in Table 5.

Table 5. Valid consent as framed by three kinds of solidarity			
	Market	Hierarchical	Egalitarian
Consent	Revealed	Hypothetical	Explicit

With respect to consent, decision makers in a market individualist context favour a *revealed preference* (Thaler and Rosen, 1975)—sometimes called *implicit consent* (MacLean, 1980). For example, if the price differential between three ladders reflects only the degree of safety built into each one and I select the mid-priced ladder I am deemed to consent to the additional risk that results from my not purchasing the costliest ladder. At the same time I am revealing that I do not consent to the increased risk that I would incur by purchasing the cheapest ladder. This principle allows market forces to determine planning priorities and the degree of risk which people are prepared to accept. The rationale is that people's preferences for one solution or another will be reflected accurately in how they spend their money.

Hierarchies tend to favour a *contractarian* principle that is sometimes called hypothetical consent (Rawls, 1971). The citizen is assumed to have entered into a contract with the decision-making institution, whereby he or she may be deemed to assent to decisions made through rational procedures of that institution, even though he or she may not like the particular outcome. For example, we pay income tax because we accept the legitimacy of the government's claim on our money rather than because we agree with the amount that it charges us. Within hierarchies, appeals to procedural fairness in obtaining consent are likely to be compared to the constitutional procedures for decision making.

Explicit consent is the only legitimate form of consent for egalitarian solidarity. The use of any surrogate for consent undermines the basic premise of egalitarianism, that all are the same and have equal say. This gives rise to particular difficulties in assigning responsibility to the present generation for the acts of our forebears as well as for obtaining consent from future generations.

Consider the claim that the North bears a special obligation to pay for climate policies based on the historical dimension of global resource use. It seems that there are two plausible lines of reasoning here. One is that children do indeed inherit the liabilities of their parents along with their assets. The other is that the historical behaviour of the North has created a current condition of structural dependency of the South upon the North.

With respect to the principle of historical obligation, it is easy to reconcile the principle that the North has liabilities towards the South, based on past resource extraction, if the relevant entities of the North and the South are judged to be legally immortal hierarchical institutions, such as corporations or nation states. This would be quite consistent with the *hypothetical consent* principles of *hierarchical* solidarity, where the individual is deemed to consent to the decisions of legitimate institutions, even though he or she might individually dissent.

However, the preferred asymmetry of losses and gains enables the egalitarian to reconcile the *hierarchical* argument about inherited liabilities with the *egalitarian* principle of *parity* advocated

Table 6. Time, intergenerational responsibility, and discount rates as framed by three kinds of solidarity

	Market	Hierarchical	Egalitarian
Time perception	Short term	Long term	Compressed
Intergenerational responsibility	Weak	Balanced	Strong
Discount rate	Diverse high	Technically calculated	Zero or negative

in the *per capita* allocation of greenhouse gas emissions. This implies that the claims of individuals take precedent over those of other entities such as states. Under egalitarian principles, an individual can only incur a debt by *explicit informed consent* and cannot be held liable for the debts of his or her forebears.

Intergenerational Equity

The argument about historical debt invites us to address intergenerational equity as an issue of solidarity across generations; how we bind ourselves to our ancestors and to our descendants. Table 6 summarises the effects of each kind of social solidarity on expectations of the future, responsibility to future generations, and determination of the discount rate.

In market institutions, expectations of the future are likely to be strongly focused on deadlines (Rayner, 1982). Competitive success depends largely on timing; planning for shifting market tastes, clinching deals at the right price, meeting delivery deadlines, or knowing when to sell pork-belly futures. The emphasis is on short-term expectations and immediate returns on activities and investments. Long-term planning is a feature of hierarchical institutions which, in principle, are immortal. Market individualists don't have time for such long-term considerations. Hence, market institutions pay little heed to intertemporal responsibility. They tend to assume that future generations will be adaptive and innovative in dealing with the legacy of today's technology, just as our generation has had to be in response to the legacy of the industrial era. So far as consent is concerned, it is assumed that future generations will make decisions on current market conditions and will therefore accept similar conditions of predecessors. The emergence of future liabilities can be left to market forces when they occur and will, in fact, provide the stimulus for future enterprise. Under these conditions different discount rates tend to apply simultaneously for different goods or at different times for the same good. The discount rates also tend to be high.

In hierarchical institutions, history is strongly differentiated. Anniversaries of great events in the past are celebrated collectively and provide models for discriminating epochs of the future. Clear recognition of age-sets and generations, which are the basis for establishing seniority in the present, also engender clear expectations of an ordered future. The regimes of distinguished leaders (whether kings or company directors) also contribute to an ordered expectation of the future. Intergenerational responsibility therefore tends to be strong but balanced by the needs of the present. It is also likely to be safeguarded by the longevity of institutions. Consent is based on the assumption that future generations will recognise the legitimacy of present institutions. The apparent discount rate, therefore, tends lower than where market solidarity applies. Furthermore, hierarchies are most likely of the three kinds of solidarity to be concerned with bureaucratic determination of a standardised rate that can be applied across the board.

In egalitarian groups also, history tends to be viewed as epochal but, because of the problems of resolving disputes in institutions that are reluctant to recognise dispute resolution by claims to seniority, competitive leadership, or established procedures, such groups are prone to frequent schism (Rayner, 1986). Hence, the group's crusading mission may lead to a sense of historical self-importance that results in the view that the present epoch is a decisive historical moment. Under these conditions, intergenerational responsibility is very strong, but trust in formal institutions is weak. If consent cannot be obtained from future generations and our descendants cannot force long-dead decision makers to pay for their errors, then we have no right to accept risks on behalf of those descendants. Under these conditions the apparent discount rate used for environmental; and intergenerational calculations are very close to zero, possibly even negative.

The different perceptions of time and expectations of the future engendered by each kind of solidarity seems to be a critical factor in the perception of the costs and benefits of climate change policies. The high discount rates and low levels of intertemporal responsibility typical of market solidarities combine to focus the attention of decision makers on current costs. Furthermore, the desired asymmetry of losses and gains leads those same decision makers to defer costs into the future where they may be capable of being dispersed more widely throughout society. Hence there is a strong incentive in market solidarity to postpone policy responses to the threat of climate change.

The low discount rates of egalitarians combined with high levels of intertemporal responsibility and the impossibility of obtaining explicit consent from future generations focus decision makers concern on potentially high, possibly catastrophic future costs. This provides a powerful incentive to take action now which, in keeping with the desired asymmetry of costs and benefits, also places the burden on the parties actually responsible for the current emissions which may impact future generations. Hence, egalitarian solidarity leads to emphasis on rapid implementation of policies designed to prevent the onset of climate change.

The technocratic approach to discounting and the overriding concern for system maintenance in hierarchical solidarity leads towards a middle course—the "no regrets" strategy of implementing climate change policies that make sense for other reasons while attempting to improve understanding of the extent of present and future costs, and when they might arise. Each of these strategies is also reinforced by the way in which each kind of solidarity leads to a different conception of human relationships with nature.

Relationship to Nature

The discussion at this workshop has focused on the issue equity in purely anthropocentric terms addressing only the issue of equity among persons, nation states, or intermediate human institutions. However, significant equity issues can be identified as arising from human relationships with nonhuman nature. I shall address some of these issues from the standpoint that our ideas about nature depend heavily on experiences of social solidarity and that the way we bind ourselves to each other shapes the way in which we bind ourselves to nature.

As Bertrand Russell observed in his *History of Western Philosophy*, "Philosophy throughout its history has consisted of two parts inharmoniously blended; on the one hand a theory as to the nature of the world, on the other an ethical or political doctrine as to the best way of living" (Russell, 1947, p.149). For example, Plato's Republic describes a political ideal of stable government presided over by securely entrenched elite. His epistemology consists of a world of forms consisting of the perfect prototypes of all worldly objects, eternal and unchanging. Marx and Engels, on the other hand, squandered a lot of time when they could have been fomenting revolutions instead of legitimating revolution through discussions of dialectical oppositions between water molecules reaching criticality at boiling point, resulting in a sudden change of state from liquid to gas; *ergo* revolutionary change is only natural (Engels, 1878).

Anthropologists have observed that it is not merely philosophers who invoke ideas about nature to justify their ethical and political preferences for proper living. We all do it. Certain traditional societies maintain that leprosy is a natural consequence of adultery, others that cattle will die if milk and vegetable products are consumed together (Elam, 1973). These are not beliefs about magic or anything exotic, but simply about nature. The point is not whether some of these beliefs are scientifically true or false, but that nature is used to legitimate value systems and that facts and values are inextricably linked together in mutually sustaining bundles. Beliefs about nature support values, such as marital fidelity or maintaining the separation of a pastoral nomadic way of life from that of sedentary agriculturalists. These values, in other words uphold principles of social solidarity. In other words, choices we make about how we bind ourselves to one another through marriage, through ethnicity, through social and economic organisation, and even the organisation of science as a human activity (in disciplines, in laboratories, in universities, etc.) shape our values and, through our values, our view of nature.

Each of the three kinds of social solidarity described in this paper is reinforced by particular view of nature. The market kind of solidarity is supported by a view of nature as *cornucopian* (Cotgrove, 1982), a flexible resource providing endless inputs for human ingenuity to create an ever increasing diversity of opportunities for growth creativity and consumption. This view of nature can be represented by the icon of a ball in a cup (Fig. 3). If the ball is perturbed, it tends to return to its original position. Intellectual justification for this view is provided by notions such as the Gaia hypothesis according to which

Fig. 3. Views of nature and ethical duties from each kind of solidarity (adapted from Schwartz and Thompson, 1990).

the earth may be a dynamic self-adjusting system in the process of developing greater capacity to absorb carbon. Certainly we know that there is a carbon fertilisation effect that stimulates biomass growth in the presence of elevated CO_2 levels. The tendency within market solidarity is to minimise any negative consequences from climate change, such as sea level rise, while also anticipating future benefits, such as CO_2 fertilisation effects and extended growing seasons. The notion that nature is extremely forgiving compounds the market tendency towards high discounting. The ethical imperative associated with this view is unapologetically *anthropocentric*. Given that nature is generous and forgiving the ethical imperative is to use nature's bounty to promote economic growth. Policies that are conceived as constraining growth are considered inequitable because they may deny the benefits of technological and economic development to those populations which are seen as underdeveloped.

At the other extreme, egalitarian solidarities tend to promote *catastrophic* conceptualisations of nature. (In contrast to the vision of infinite growth, the concept of *carrying capacity*, which presents the earth as a fixed pie, explicitly links the concept of fragility to the issue of fair shares.) The appropriate icon here is a ball balanced precariously on an upturned cup, where any perturbation would result in an irretrievable loss of system stability. The notion that nature is extremely fragile adds urgency to the already compressed time structuring within egalitarian solidarity which further compounds the tendency towards zero or negative discounting.

The fragility of nature is frequently conveyed through the photographic image of the earth from space.

> Perhaps the most poignant image of our time is that of earth as seen by the space voyagers: a blue sphere, shimmering with life and light, alone and unique in the cosmos. From this perspective, the maps of geopolitics vanish, and the underlying interconnectedness of all the components of this extraordinary living system—animal, plant, water, land, and atmosphere becomes strikingly evident. (Benedick 1991, p. 199)

This immensely powerful symbol consists of three elements. First, the imagery of the earth itself emphasises fragility. The adjectives "blue", "shimmering", and "light", all evoke, and are designed to evoke, a delicate object, easily broken. "Alone" and "unique" stress another aspect of vulnerability that the object, once lost or shattered, never can be rescued or restored. The second element in this symbol evokes the complexity and interdependence of the systems of life on earth. Interestingly, in addition to land, water, and atmosphere which are clearly visible in such photographs, the writer supplies the details of plant and animal life, which are not observable, as if they are part of the visible image at the global scale. The third component of this symbol emphasises the claim that human divisions, "the maps of geopolitics" are somehow artificial illusions of local ethnic, political, and economic independence that vanish once the quintessential truth of environmental interdependence is grasped. What is presented as a simple perception of reality is really a carefully constructed mythic vision of a fragile system of natural interdependence endangered by our own hubris.

The strong sense of interdependence that exists within egalitarian solidarity supports the extension of rights and ethical responsibilities to nature itself, hence it is among egalitarian institutions that we encounter strong support for the notion of animal rights and even rights for plants and geological formations (Stone, 1972). Such an extension of equity concerns to the non-human world is infrequent among market or hierarchical solidarities. There is therefore a strong ethical supposition that interference with natural systems, such as the climate system, is inherently unethical.

Between these extremes, hierarchical solidarity promotes a view of nature as stable within certain limits that may be hard to define in advance. This world view tends to be supportive of innovation in the shorter term but also wonders about the long term sustainability of the system under pressure. The appropriate icon here is of a ball rested in the depression of a saucer. Some perturbation is possible, but not too much. The challenge to the scientist and the policy maker is judging how much the system will bear. The notion that nature is *manageable* technocratically compounds the tendency to attempt to devise technical rules for standardised discounting.

A Two-Dimensional Map of Human Values

In the preceding sections we have summarised a wide range of social science insights into the three most basic ways in which people bind themselves to each other in social institutions and, in so doing:

- define their own basic needs,
- develop preferences for distributional equity,
- establish principles of procedural fairness,
- establish principles for intergenerational equity, and
- shape their epistemological and moral relationship with nature.

These summaries provide us with a basic two-dimensional map of the diversity of human values. The triangle is equivalent to the territorial borders of a conventional geographical map. Using the same outline, separate maps can be drawn for each element of equity, just as atlases contain maps of precipitation, vegetation, population, and other variables of interest that are superimposed on the land surface. Often several maps can be overlaid to give a composite picture as I have done for the map of human values in Fig. 4. This analogy with geographical maps is helpful precisely because such maps always tie the variable of interest to a particular location having specific geological characteristics that support the variable. In other words, precipitation, vegetation, population, etc., are not free-floating, but tied to specific places on the land surface. Similarly, the map of human values is not just a free floating suite of ethical options. It locates packages of values and ethical priorities in specific places in the social landscape; that is within institutions exhibiting various mixtures of market, hierachical, or egalitarian solidarity.

Fig. 4. Basic map of human values.

The analogy with geographical maps is also useful in that maps can be drawn at different scales. Similarly, the map of human values can be drawn at a variety of scales. The family, the workplace, and the community all depend on the creation of solidarity among individuals. The corporation, the nation state, or the global community of nations are examples where solidarity is built among larger aggregations of people bound to each other in various ways. Ultimately, the issue of climate change, in particular, and global sustainable development, in general, is a challenge to create and maintain solidarity at all of these levels. The two-dimensional map provides us with a richer analytic framework than one-dimensional approaches for understanding and intervening in ethical disputes in the formation of treaties, the implementation of national policies, the shaping of consumer demand, and the modification of behaviour at the micro level of firms and families.

Another feature of geographical maps drawn to scale is that they enable a navigator to locate his or her position in relation to other locations and to measure how close or far that is from various objectives. Although I do not have space in this discussion to go into details, systems of mathematical measurement of market, hierarchical, and egalitarian solidarities already exist at the level of communities and organisations (Gross and Rayner, 1985) and of families (Dake and Thompson, 1993). Similar measurement schemes could easily be adapted for measuring solidarities among larger units such as nation states. Negotiators can use the map of values to locate their own position, to select the direction in which they want to move in any dimension of equity, and to measure, on multiple criteria, the distance between their own positions and the goals of other participants in a negotiation process.

At the very least, use of the map could lead to technical improvements in the kind of benefit-cost analyses already being performed within the IPCC framework. For example, the map of human values rests on the processes of creating and maintaining social solidarity in both space and time. Hence it provides a theoretical basis for developing predictive models of institutional differences in principles of intergenerational obligation and social discount rates, which are key to the success of welfare economics, but into which welfare economics itself provides no insight.

In fact, welfare economics as a prescriptive value system has its own place on the two-dimensional map. The dominant concern for efficiency, embodied in the drive to achieve Pareto optimality, is characteristic of market solidarity. However, within welfare economics, the market orientation is modified by hierarchical concerns to apply the efficiency criterion to administrative determinations of fairness. This locates welfare economics along the left side of the triangle between market and hierarchical approaches. Thus, the triangular map graphically reminds us to consider alternative utility functions that value equality over efficiency and refuse to discount future costs. While some economists may be tempted to argue that such egalitarians are too few to matter in the grand scheme of things, those who study the dynamics of scientific and technological disputes will attest to the effectiveness of such parties in slowing or preventing the implementation of a variety of projects and programmes including hazardous waste facilities, nuclear power programmes, and genetic engineering research development and marketing (Johnson and Covello, 1987).

By focusing on the construction and maintenance of institutional solidarities, rather than focusing on the preferences of individuals, the map also provides a basis for developing models of changes in societal preference functions. Furthermore, we can better appreciate how the individuals can make radical shifts in their individual preference functions without resorting to the conclusion that they are either irrational or acting in bad faith. For example, a negotiator from a developing country elite may invoke the *parity* principle in international negotiations, the *proportionality* principle in apportioning budgets in his or her domestic bureaucracy, and the *priority* principle in making his or her own domestic private sector investments. Rather than cynically switching values in the pursuit of naked self-interest, the map suggests that the same individual may simply be involved in building different kinds of solidarity in different spheres of activity. Each package of principles for defining needs, preferences for distributional outcomes and procedures, responsibilities to future generations, and establishing obligations with respect to nature is stabilised institutionally in the creation of social solidarity. Hence, while individuals may be inconsistent in selecting elements from each package, institutions exhibit greater stability and predictability, and may be a more appropriate site for analysis than individuals.

Furthermore, as Rose (1990, p. 927) observes, while there is good consensus among welfare economists on Pareto optimality as the best efficiency criterion, "there is no consensus on a 'best' equity principle". The two-dimensional map enables us to add a refinement to this observation; that is, we probably should not even attempt to find a "best" equity principle, but should focus instead on achieving practical agreement about joint action among parties upholding quite different, even incommensurable principles of equity. In other words, the IPCC should shift its sights from a *technocratic* goal of providing decision makers with the best possible prescription for fairness towards the more modest goal of providing decision makers with the best tools for essentially *political* negotiation among competing prescriptions. As Rose (1990, p. 934) concludes, "The fact that there are several alternative definitions of equity should not give cause for dismay but, rather, should stimulate further study. In principle, nearly all nations ascribe to some concept of fairness, and thus its potential as a unifying principle should not be neglected". A concept of fairness that acknowledges diversity across more dimensions than distributional outcome alone seems more capable of engaging diverse actors than a one-dimensional conception that may require participants to violate their values and preferences on other dimensions of equity.

This conclusion is consistent with the advice of decision theorists, that parties seeking agreements on actions should seek to include a wide range of dimensions in their negotiation (Fisher and Ury, 1981; Raiffa, 1982). To design *win-win* solutions in negotiations, we need to be able to recognise what counts as a *win* to the parties involved. As Table 1 illustrates, winning consists of more than just the bottom line from a single transaction. We can now elaborate that example by suggesting that building communities at the local and global scales is a highly valued goal of human behaviour. For instance, the US State Department frequently argues that participating in international environmental agreements enhances US leadership and credibility in the international community. This desire to promote goodwill and solidarity among nations may well override concerns for the domestic costs of participation (Hahn and Richards, 1989). The map of human values provides a systematic tool for exploring multiple dimensions of fairness in the search for practical agreements.

In conclusion, I have described a moral landscape and an approach to mapping it that presents a picture of equity concerns that are likely to influence the conduct of climate negotiations and efforts to implement climate change policies. This landscape is more complex than the one-dimensional analytic framework that currently dominates the discussions of equity within the IPCC. However, it remains reasonably parsimonious and has clear practical implications for the conduct of research and negotiations and the implementation of climate change policies designed to address the decision stakes as shown in Fig. 1.

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Evaluating the Use of Global Commons: Lessons from Research on Social Judgment

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Abstract—Judgments in social relations have extensively been studied in social psychology and neighbouring disciplines. Equity and equality considerations, cognitive and motivational biases establishing states of (in)justice have been identified. It is argued that besides general climate change-related perceptual biases, user groups are interested in presenting the own party at a disadvantage. Selective considerations on justice, equity and equality contribute in achieving this goal. Furthermore, they serve as prominent justifications for social influence processes. An application of results and models to relations defined by interdependence via use of global commons is overdue. Justice considerations in interpersonal, intergroup and intergenerational relations have to be studied on various levels (individual, group, society, culture) in order to comprehend perceptions of, decisions for, and contributions in using global commons as well as comparative evaluations of being affected by others' use. Global (climate) change-related features result in specific outcomes of commons-related accounts. These are determined by core features of global environmental developments: environmentally and socially uncertain (including uncertainty about what "common interest" or "sustainability" means), perceptually, temporally and spatially indirect or mediate, rare, distant in actor-victim relation, and finally providing low advantageousness of behaviour not based on immediate self interest.

Within the context of social sciences, psychology is stereotyped as a discipline focusing and modelling individual-centered variables and processes. Thus at a first glance, the role of psychological explanations within climate change research may be obscure. As soon as climate change-related issues are reflected in relation to actions and re-actions of human systems however, the importance of explanations offered by psychology becomes visible. If, moreover, the attention is immediately directed to issues like equity (Kasperson and Dow, 1991; Zimmerman, 1993) and social considerations which in psychology are addressed extensively and in various areas, the inclusion of this discipline's considerations becomes self-evident. Interdependence, extendedly discussed in social psychology (Deutsch, 1982; Kelley, 1984a, b; Kelley and Thibaut, 1978), will turn out as an important concept to explain equity considerations.

Facing the facts that there is (a) an immense body of studies on social judgments including equity and equality considerations, which (b) are—in many respects—genuinely social, and that (c) psychology's contribution to research on climate change is demanded increasingly (Jacobsen and Price, 1990; Fischhoff and Furby, 1983; Lévy-Leboyer and Duron, 1991; Lowenthal, 1990; Miller and Jacobsen, 1992; Pawlik, 1991; Sjöberg, 1989; Stern, 1978a, 1992; Stern et al., 1992; Whyte, 1985; Worcester and Barnes, 1991), it should be obvious that a review on the scientific state of the art on climate change-related aspects of equity and social considerations definitely has to include psychological explanations.

In social psychology, topics like justice, equity and equality are studied as outcomes of social cognition. It has been investigated how single individuals or individuals as members of social categories evaluate social relations as just or unjust, equitable or inequitable, equal or unequal. The major focus has been on distributive or procedural justice. In assessing psychology's contribution for the given topic, it has definitely to be kept in mind that explanations are focused on variables and processes constituting the evaluation of justice, which must not be confused with an explanation of justice itself. This is not at all a deficit. Trying to comprehend climate change-related activities of human beings, groups, societies or generations; and taking the fact that these activities are interdependent seriously, the construction of justice by involved individuals or

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groups becomes a core feature of explanation.

Studies on commons dilemmata (Edney, 1980; Grzelak, 1994; Harvey et al., 1993; Knapp, 1993; Martichuski and Bell, 1991; Mosler, 1993; Stern, 1978b; Tsai, 1993; Wiener, 1993; Wit, 1994) show that justice-evaluations not at all are merely cognitive but additionally provide orientations for behavioural decisions. These are self-referential (baseline, goals) as well as social (norms, justifications, claims). Both functions have to be reflected in models explaining climate change-related behaviour of human systems like use of resources, conflicts and negotiations about exploitation and emission rights in environmental-economic accounting.

Applying these results to the topic in question we will discuss features of the global community and attributes of the most alarming indication (global climate change) in more detail before—as a conclusion—dimensions of commons-related justice considerations will be introduced.

To illustrate the goal of our contribution and to tailor expectations, we are interested in explaining processes like the following:

In case an individual / a group / a society is confronted with the reproach of executing an impact threatening sustainability, he/she is interested in

(a) de-evaluating the danger
(b) evaluating the impact of alternatives negatively
(c) ignoring the existence of alternatives (or keep their number low).

Referring to others he/she will in contrast

(d) underscore the negative impact of their behaviour
(e) stress the positivity of (not selected) alternatives
(f) emphasise the existence of a wide number of alternatives.

I. Recognised Interdependence as Core Feature of Human Systems

Without referring to the philosophical discussion of the specific position of men in nature explicitly, we have to discuss two basic features necessary to develop our argumentation. Firstly, human actors are generally able to reflect their function within the earth-system; secondly human actors are interdependent within the system. Consequently, human actors are able to recognise their interdependence. In the following section, we will argue that the outlined competencies not at all necessarily mean that impact assessment or interdependence assessment have to be "correct" (irrespective of difficulties to find a criterion to define this). On the contrary, there are convincing reasons to expect failures and shortcomings (which are discussed e.g. in sociology, too; Luhmann, 1986). The anticipated errors and biases are not arbitrary. Research on social cognition will help us to anticipate systematics. We will use the model of an "active filter" to illustrate the function of selective and biased perception and assessment.

Human Actors are Self-Reflecting Elements Within the Earth-System

A feature frequently stressed in characterising human components within the earth-system is their ability for self-reflection. From their respective points of view, individuals are agents, observers, and/or victims of the system's state and development. This perspective on man's function within the system enables us to refer to existing knowledge and evaluate its potential for explaining single individuals' or aggregates' interdependence via their use of global commons.

Psychology has elaborated some models competent to explain the functioning of the active filter "human perception and evaluation". These may be applied to

- representations of the system's status quo (including motivational and cognitive strategies to ignore undesired functional relations or to understate their importance),
- representations of the system's probable development (including motivational and cognitive strategies to ignore high probability of undesired scenarios, irreversibility of developments or critical states).

The active filter "perception and assessment of climate change" has an important function in coping with embarrassing information. Taylor (1989) points out that self-deceptive "positive illusions" serve as means to cognitively handle undesired knowledge. It has to be expected not only retrospectively that humans evaluate facts more positively than they have been classified *in situ* (hindsight bias). With respect to fuzzy topics (like climate change) and with respect to future developments and ambiguity, this tendency has to be anticipated, too. Furthermore, we must expect this trend to increase with the degree of discomfort associated with the information.

With respect to climate change, these results let us expect a general bias to underestimate the fact of change itself and also the severity of its impact—particularly under conditions of informational or evaluative uncertainty (Tversky and Kahneman, 1974, 1978). The motivational assumption for expecting positively biased perception and assessment primarily refers to the victim's perspective. Taylor and Brown (1988) explicitly discuss mental health aspects in explaining such positive illusions. Admitting the fact that the global human user community (including the own person or group) faces extreme impacts of climate change within the near future would be threatening. This cognition thus has to be avoided from the victim's position. In the given context, this is likely to be done by preferring information which highlights the ability of the system or its human components to cope with climate change or refuses that climate change is actually happening or anthropogenuous. Arguments clearly supporting this position are found in the climate change debate. We will continue discussing this in sections II and III, after some differentiating conditions of the outlined tendency will be introduced in the next section.

A further shortcoming of the self-reflecting user community is caused by the limited capacity of the human mind in reflecting variables (Dörner, 1985; Dörner et al., 1983). Besides the above mentioned motivational strategies, cognitive tactics of reducing complexity or coping with uncertainties have to be expected. Preference for monocausal explanations, tendencies to apply available models and not to develop new concepts as well as to overestimate effects considered as representative for a specific phenomenon have been identified in studies on lay epistemology. The need for simplification applies to relatively rudimentary causal relations, illustrates difficulties in realising simple interactions, and is even more relevant in explaining complex processes or nonlinear dynamics like those affecting humans and affected by humans on the planet Earth. In commons-related equity considerations, this types of simplifications have to be expected as additionally influencing perceptions and evaluations. In combination with further actor-related considerations on motivational biases, these cognitive tendencies are expected to be not arbitrary but systematic.

Human Actors are Interdependent Within the Earth-System

Additionally to the outlined tendencies, psychological research on attribution of causality and responsibility leads to further assumptions from the actor's perspective. An application of these results brings us closer to considerations on equity and justice which are observed in individuals, societally shared, and met in negotiations.

Monitoring studies of our ecosystem increasingly indicate that our planet's capability to cope with human impacts is limited. Accepting the model of a human "user community" which is underlying the concept of "global commons", this evidence means, that individuals or groups are interdependent via use of global commons (Linneweber, 1994). While developments or events of extraordinary significance like effects of acid rain or the Chernobyl accident more clearly indicate dependence-structures related to the environment, this is less obvious in global and thus fuzzy developments like depletion of stratospheric ozone layer, global warming, loss of biodiversity. Here, dependence and interdependence-relations are subject to constructions which are—in the line of the argumentation developed in this contribution—expected to be biased, too. In case of independent users, equity considerations would apply only if gains or losses provided by the system are allocated by agents who can be made responsible for distributions regarded as unjust. This however, presently is limited to human agents defining entitlement. With increasing evidence of global interdependence it becomes clear that it does not apply to global commons. As soon as the global community moreover has succeeded in defining and allocating exploitation and emission rights, these permits additionally will be (and have already started to be) subject of justice and equity considerations. Interdependence thus is given with respect to using opportunities as well as using reglementations. Both are interconnected. Losses as well as gains caused by interdependence will be defined and referred to in order to justify entitlement or compensations. In order to understand and optimise impending discussions and negotiations on global and climate change-related equity, the outlined position of systematically biased and perspective-related perceptions of interdependence seems useful.

With respect to global commons, individuals, groups, societies or nations are not only interdependent at a given point in history, but also intergenerationally. Commons used or down-cycled today may not be used tomorrow; biodiversity definitely lost by impacts one group of users is responsible for, cannot form grounds of living in other areas or times. The notion of interdependence has to be considered as a necessary condition for equity and other social considerations. Within the global user community, interdependence relations increasingly become evident—particularly as limits of our planet's carrying capacity gains visibility. In the following section, we will show that the manifestation of concrete interdependence relations again is to be understood adequately as a construction of the system's human elements.

Human Actors are Capable of Their Interdependence

Besides dependence and interdependence relations "objectively given", the introduction of the active filter "human perception and assessment" additionally inaugurates space for constructions of interrelatedness. We may expect further products of the self-reflecting activity of the earth system's human components. Once again, these are not merely products of cognitive activity but of functional significance in use of global commons and negotiations about it.

Interdependence-related products of the active filter perception and assessment are:

- comparative representations of own person's/group's vs other person's/group's
  - affectedness by,
  - causation of,
  - responsibility for

current state, past or future development of the system as a whole or separate aspects with immediate, mediate, and global effects.

The interdependence-structure of the system includes that representations of contributions necessarily are comparative. Not absolute losses or gains guide decisions in using global commons but contributions compared to others. Research on distributive justice shows that relational effort/outcome ratios constitute the basis of equity considerations. In the given context however, criteria to define efforts and outcomes (in positive as well as negative terms) again are fuzzy and moreover multidimensional. This offers room for biased evaluations of importance and accounting of results.

With respect to relative affectedness by climate change (i.e. the victim's perspective), the involved parties will underscore the magnitude of their negative outcome and additionally emphasise the importance of the affected dimensions. In contrary they will stress their own effort to conserve or protect the global commons and de-evaluate efforts of other users. Models for environmental-economic accounting have to keep in mind these biased perceptions of involved parties and must include that criteria, relations and their weight, as well as accounting itself are object of negotiations.

Given the fact that the causation of climate change by single actors or groups consensually is considered as negative, actors are motivated to avoid responsibility for this. Several tactics or strategies achieve this goal. It is likely that these are implemented consecutively and that underlying hierarchies show similarities to those identified in research on account episodes (Buttny, 1993; Schönbach, 1987, 1990, 1992). Hence it is expected that preference is given to refusing causation by the own party. Argumentation about environmental change-related justice denying causation is frequently met in intergroup or international negotiations. We will show later that the topic is destined for this type of argumentation. If refusing causation is impossible, responsibility may be rejected by arguing "I/we cannot do otherwise" or "we are forced to do so" or "the situation requires our actions". Thus external conditions or other agents are likely to be made responsible in case of clear causal evidence. External influences may be constructed immediately or in a mediate way, they necessarily assume dependence structures discussed by the second assumption.

Closing the considerations on biases of climate change-related self-reflections on interdependence it has to be stressed that in the position of actors, the tactic mentioned first and associated with "positive illusions" is more likely to be applied. This means that besides general tendencies to underestimate negative developments and reduce complexity, actors have additional reasons to formulate positive illusions with respect to changes they have caused or are made responsible for.

(Re-)presentation of Interdependence to be Studied as Product of an Active Filter

Taking a closer look at features of the active filter "human perception and assessment" helps us to explain man's role in the biosphere like resource-oriented, regeneration-threatening, and reproductory behaviour ("critical" with respect to scenarios of the system's long-term functioning). It also explains social, organisational, and economic influence processes towards critical behaviour of others or omissions of possible influences. The interdependence structure frequently stressed above includes that these influence processes are systematically related to biased evaluations of equity relations. Social sciences are challenged to extend their knowledge of these processes.

One way to achieve this goal has been selected here: applying existing erudition to the topic climate change. Concluding some research gaps evident from above considerations will be summarised.

Directly associated to the outlined position are some research goals to be addressed in social scientific climate change research. Interpersonal, intergroup and intergenerational relations have to be studied as objects of justice considerations. As part of analyses on climate change-related self-reflections of interdependence, this has to be done on various levels in order to develop a complete understanding of this part of human driving forces. With respect to individuals, analyses of equity accounts contribute in explaining behavioural decisions like acquisition or use of "critical" (in the above sense) instruments or substances. In case of given behavioural choice, analyses of justice considerations contribute in explaining the use of decisional freedom. An understanding of these processes functions as a kind of bottom-up explanation.

Individuals, however, also act as "mega-actors"; they determine degrees of freedom for users or user groups. This applies to governments, administrations as well as in economics. It should be obvious that equity accounts of "mega-actors" are highly influenced by their own justice considerations. Moreover, they are interested in anticipating decisions and behaviour of persons they try to influence. Thus they elaborate hypotheses of users' "naive" concepts including justice considerations. Social scientific research on climate change has to focus these meta-models in order to understand highly influential decisions of mega-actors and their contributions in negotiations.

On aggregated levels of groups, societies, and cultures, climate change-related equity considerations have to be studied in order to comprehend perceptions of, decisions for, and contributions in using global commons as well as (comparative) evaluations of being affected by others' use. Intergroup, intersocietal and intercultural social comparisons have to be focused.

II. Features of Global (Climate) Change

It has been mentioned above that the topic climate change is predestined for biased and erroneous perceptions and evaluations discussed so far. In line with Pawlik's (1991) reasoning on global environmental change, we can relate climate change-specific attributes to the processes discussed above. Since we have shown that equity and other social considerations are based on "naive" reflections of interdependence, attributes of the topic in question have to be considered as determining these reflections.

According to Pawlik's (1991) considerations and slightly extended, the determined core features of global environmental developments are:

- environmentally and socially uncertain (including uncertainty about what "common interest" or "sustainability" means),
- perceptually, temporally and spatially indirect or mediate,
- rare (events of low probability),
- distant in actor-victim relation, and finally
- providing low advantageousness of behaviour not based on immediate self interest.

This has to be discussed in more detail. Developments summarised as "global environmental change" are fuzzy. Firstly, they are environmentally uncertain. There are still disputes in natural sciences how to interpret monitoring data. On most variables, the signal-to-noise ratio is not only perceptually low but, moreover, opens room to controversial interpretations within the scientific community. The impact of this uncertainty on the public discussion and hence "naive models" is obvious. Processes discussed above are enhanced under conditions of uncertainty or ambiguity. Biased perceptions of equity considerations are most likely to occur, and there is plenty of room to develop argumentation supporting the respective own position.

Secondly, global environmental change including climate change is socially uncertain (Wit, 1994). An identification of responsible impacts and actors still is difficult. Even in local events like pollution of water, responsible actors sometimes are hard to identify. Significantly more difficult turns out to determine responsibilities with respect to global developments or relative contributions to accumulating, interconnected and synergetic processes. Also, on the side of affected parties, social uncertainty occurs. Studies on environmental equity related to exposure to hazardous material like waste disposal sites (Kasperson and Dow, 1991; Zimmerman, 1993)—again geographically rather precisely defined—end in complex interpretations. Even more ambivalent losses in using of global commons are to be expected. Involved user groups can mutually attribute gains or only small losses to others and claim being affected seriously or profiting only marginally.

With respect to the system's development, considerable uncertainty about what "common interest" or "sustainable development" means, and how to behave in order to achieve these goals, results from this. Considering that contributions in environmental protection or restrictions in exploitation are consensually justified by these goals, the traced uncertainty includes self-serving opportunities in presenting own contributions for involved parties. The debate on use of nuclear power in industrialised countries shows that pro-arguments are formulated by highlighting aspects like conserving fossil fuel, low CO_2 emission rates and by de-evaluating implications like long-term storing radioactive waste. These arguments definitely refer to the orientations "common interest" or "sustainable development". Exactly the same points of reference are alluded to by opponents of this energy policy.

Global environmental change is further characterised as perceptually, temporally and spatially indirect or mediate (Pawlik, 1991). Psychological research shows that the more direct cause-effect relations are, the more motivation to change behaviour causing a specific effect is developed if the effect is individually or socially undesirable. Each of the three aspects offers room for avoiding unpleasant cause-effect perceptions. If not resulting from immediate perception, disliked events may be attributed to the perceptual process itself. If not temporarily or spatially immediate, alternate causes may be preferred. What qualifies favourable alternatives does not have to be discussed again.

The fact that immediate evidence of global environmental and also climate change like flooding of coastal zones, periods of extreme weather is still rare, has an impact on the construction of justice and equity. Events of low probability are easily to be de-evaluated in their indicative significance—although, as mass media interpretations of e.g. long, hot periods, hurricanes and floodings show, they can also be easily overestimated with respect to their indicative meaning. This interpretational ambiguity additionally threatens their credibility.

The distance in actor-victim relation, a further core feature of global environmental change, similarly implies a high amount of interpretative freedom. Like in social contexts, responsibility for undesired states or developments may be denied by referring to other agents. Efforts to approach presumable actors are high. Social distance, group membership, nationality or culture act as further barriers. Furthermore, persons or groups directly affected only in rare contexts are those immediately approaching actors. Negotiations on responsibility mostly take place among indirectly involved parties. These aspects have to be taken in consideration if climate change-related equity considerations and argumentation based on these are of interest.

Finally and most prominently characterising psychological implications of justice considerations in using global commons, behaviour not based on immediate self interest proves low advantageousness. The discussed aspects like uncertainty, low probability and delay and of being made responsible contribute in enhancing the attractiveness of egotistic use. Moreover, the fact that competitive acquirements continuously enhance valuable positions like standard of living (related to others) complete the outlined pattern of self-serving interpretations most likely to be met.

III. Dimensions of Global Commons-Related Justice Considerations

As a conclusion from section I and II, four dimensions of global commons-related justice considerations will be introduced.

Point of Reference

According to relevant writings on human dimensions of climate change, we have differentiated positions of actors and victims. These, however, are not definite and may be defined only temporarily or by accentuating positions. Human components within the Earth system are actors and victims of global environmental and climate change at the same time. If however groups are differentiated, and as being easily observed in negotiations, argumentation in the climate change debate and thus equity considerations may be differentiated as

- referring to the position of victim of global change—or
- referring to the position of actor (agent) of global change.

We tried to show reasons why the former position is preferred. This point of reference allows to formulate aspirations, to demand compensation for own losses, and to claim higher exploitation rights. The latter one is less attractive, and defensive strategies like outlined above may be expected. Due to the argument that positions *a priori* are indefinite, in negotiations we must expect additional strategies of involved parties. These are oriented towards the goal of defining the own position in a favourable way by selecting topics or dimensions. French representatives will be more likely to engage in CO_2-related negotiations than members of other industrialised countries; delegates from Mauritius will be more willing to discuss population development rates as driving force of global change than a Kenyan commission. The evaluation of climate change-related relevance of processes and impacts is expected to systematically vary accordingly.

Period of Reference

Justice or injustice is not just given at a definite point of time but develops in decades or centuries. Moreover, justice considerations in present argumentation refer to probable future developments. The temporal dimension of justice considerations can be defined as referring to the

- past (retrospectively referring to own vs others' past contributions)
- present (including constructions of interdependence in facilitation and constraints)
- future (with respect to own vs others' contributions and developmental potential).

This again opens space for interpretative ambiguity. Past developments may be reconstructed according to self-serving goals discussed above. In the same way, scenarios of future developments are more likely to be accepted, if e.g. the own party probably will be disadvantaged with respect to global commons or if impacts of own activities are considered as being harmless or compensated easily. The selection of periods of reference additionally is likely to be biased. Research on interpersonal conflict shows that the reconstruction of episodes and phases are extremely biased in position-specific referencing. Also negotiations among nations, e.g. on territorial rights indicate the relevance of periods of reference.

Qualities of Global Change-Related Justice Considerations

The interdependence assumption logically implies that parties are interdependent. This has been discussed above. Two specific qualities of justice-considerations make use of this. Reflections on commons-related justice are

- comparative (and thus necessarily biased)
- selective (and thus additionally biased).

The comparative quality is a necessary condition for applying equity considerations at all. The selective quality has multiple effects. Firstly, objects for comparison may be selected. This refers to temporarily (periods of reference) as well as spatially (groups of reference) defined entities. Secondly, resulting from the multidimensionality of climate change, variables for comparison processes may be selected. Principles guiding these selection processes have been frequently discussed above and need not be repeated here. Social psychological research on intergroup relations indicates a high creativity in selecting entities for comparison processes which perfectly serve goals of positive distinctiveness. Undoubtedly, this has to be expected in the given context, too.

Functions of Global Change-Related Justice Considerations

In dynamic contexts, justice considerations do not merely have the goal of accounting but implicitly enable involved parties to justify behaviour and formulate claims. In the given context, climate change-related justice evaluations function

- between groups (as justification of own contributions)
- within groups (to define goals and justify efforts for developments).

While the between-group function has been discussed extensively, it should be added that evaluations on global commons-related equity have an important function in within-group contexts, too. As the between-group and the intergroup functions are interrelated, the latter has to be considered in explaining the former and vice versa. Within societies, the definition of goals and justification for environment-related efforts are immediately related to comparisons with external entities. Depending on the selection of entities of comparison, the formulation of goals and justification of efforts varies extremely. Debates on global commons-related obligations within societies indicate how sensible results in applying justice principles are.

IV. Appendix

Justice Principles: Equity vs Equality

So far, we have primarily referred to the equity principle in justice considerations. In social sciences, it is frequently stressed that this is not the only concept to be applied. Although less frequently discussed, the equality principle must not be ignored. Especially in the given context, equality considerations guide international conventions considerably.

The impact, different justice principles may have in intra- and international negotiations on e.g. emission rights, may be shown in the following way: applying the equality principle would mean equal emission rights for every person in whatever country. This principle is applied by those pleading that the life of a person has to be calculated equally irrespective of being a citizen of New York City or Bombay. This is of course in accordance with principles of high ethical status. Applying the equity principle, however, could imply that a criterion to calculate emission rights is taken into account: in this case, higher emissions would be justified if a person/group/nation/generation contributes in a way being considered as positive for the system's functioning. If e.g. the implementation of an energy conserving or CO_2 reducing technology temporarily includes high emissions (or other type of negative impact), he/she would be justified to execute this.

From the discussion above, it should be immediately obvious what the application of the latter principle implies: the evaluation of a contribution with negative impacts justified by serving "common interest", is a matter of definition and thus subject to highly biased and certainly self-serving (re)presentation of the system's functioning. It will be also a matter of equity negotiations how to detach and calculate immediate and mediate, own and common interest and benefit.

Summarising, it has been argued that models on human dimensions of global environmental change have to include justice and equity-related aspects of self-reflecting human systems. The outlined core features of environmental change as well as the accumulated knowledge on biases and errors in judgmental processes have to be integrated in order to comprehend individual or collective contributions of threats to the system's sustainability and to develop alternatives.

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From Sacred Being to Market Commodity: The Selling of the Commons

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Abstract—This paper distinguishes the use of the word "culture" in indigenous and modern societies. It describes the integrated world view of indigenous societies, traces the separation that has occurred in modern society among nature, culture, science, economics and religion and identifies this separation as being at the root of the climate change crisis. Finally, it describes the current process towards reintegration, in particular, the recent work of the World Council of Churches on climate change.

> *We know that the white man does not understand our ways. One portion of the land is the same to him as the next, for he is a stranger who comes in the night and takes from the land whatever he needs. The earth is not his brother, but his enemy, and when he has conquered it, he moves on... He treats his mother, the earth, and his brother, the sky as things to be bought, plundered, sold like sheep or bright beads. His appetite will devour the earth and leave behind only a desert.*
>
> Chief Seattle, 1854[2]

Culture, Religion and Environment in Indigenous Societies

There are two main definitions of culture, one which is generally applied to indigenous people, the other used mainly when referring to modern society. With reference to indigenous societies, culture may be defined as "the totality of socially transmitted behaviour patterns, arts, beliefs, institutions, and all other products of human work and thought characteristic of a community or population". With reference to modern society, use of the word "culture" is generally restricted to "intellectual and artistic activity".

When the Maasai think "culture", they think of their age groups, the traditional system through which they manage their society and their resources. When Northerners think "culture", they think of art, literature, music and theatre.

Religion is defined as "the expression of belief in and reverence for a superhuman power recognised as creator and governor of the universe".[3] Environment, simply, is that which surrounds. It is generally taken to include both physical and social circumstances that affect growth and development. Environment may be culturally defined as both "a source of problems and the context of solutions".[4]

The distinction between environment, culture, and religion is an artifact of a particular society's definitions.[5] "With increasing knowledge, it becomes difficult to separate the categories of 'Nature' and 'society' or 'Culture', except in terms of cultural perspectives. That which is seen as belonging to the category of 'Nature' in one society may be conceptualised as belonging to 'culture' in another".[6] There is no word for religion as such in the traditional language of the Maasai peoples of Kenya and Tanzania. But the Maasai have common cultural experiences that are clearly religious in their ability to renew the hope of the people and sustain them spiritually from

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[2]Cited on p.12 in *Traditional Ecological Knowledge. Concepts and Cases* (Edited by Julian T. Inglis) International Programme on Traditional Ecological Knowledge and International Development Research Centre, Ottawa, 1993.

[3]Definitions from *The American Heritage Dictionary of the English Language*, New York, 1969.

[4]Paula Jean Williams. "The Social Organization of Firewood Procurement and Use in Africa: A Study of the Division of Labor by Sex". PhD Thesis, University of Washington. p.38.

[5]Ibid., p. 44.

[6]Ibid., p. 44.

generation to generation.[7] In indigenous societies, culture, religion and environment are aspects of one integrated whole usually subsumed under the word "culture".

There are various theories about the precise nature of the relationship between culture and the environment which have been classified under the headings deterministic, voluntaristic, and processual.[8] The specific nature of the cultural/environment relationship is not relevant to this paper. What is important here is the general agreement that indigenous cultures have developed in direct relationship with the particular ecosystems in which they reside.

Resource use is the concrete mechanism by which human-environment interactions occur. Since movement of indigenous societies is limited by definition,[9] these societies have developed using only the resources available in the places where they live. Destruction of these resources constitutes an immediate threat to society. Thus indigenous cultures have evolved a profound knowledge of their local ecosystems and developed systems for the sustainable management of those ecosystems.

The process from environmental experience to culture may be described as follows. Over time, experience about resource use builds up and knowledge is transmitted from generation to generation. This knowledge about the environment and its transmission shapes culture, and culture in turn shapes knowledge. These are reciprocal phenomena. During knowledge transmission over several generations, social institutions are gradually crystallised. Routine or habitual ways of doing things gradually become the customary way that things are done. For children, a community's customary way eventually becomes the given-received social world, an analog of the biological-physical world with which it overlaps.[10]

The institutionalisation of human-environment interactions defines how people will interact with each other and with their environments. It defines what aspects of the environment will be valued as resources and how resources are to be used. It provides the framework through which elders advise and teach, and it ensures access to resources by all members of the community. Institutionalisation also permits specialisation/division of labour (e.g. gender roles) for more efficient resource management.[11]

Frequently, environmental knowledge is articulated within a context of spirituality, and it is expressed in terms of roles, respect and responsibilities.[12] Professor Elizabeth Reichel defines Shamanism, a religion practiced by over 30 million Amerindians, as "a form of eco-politics, a mechanism for the regulation and control of resources". She says that shamans practice environmental "accounting": An awareness that action upon the environment always begets reaction. "These indigenous societies can be said to be among the few ones left with a strong cultural tradition of indigenous sustainable development".[13]

Thus traditional communities could be given credit for the concept of sustainable development. "Indigenous peoples have lived within the means of their communities its land and its resources. They have conserved natural resources while thinking of other communities and future generations".[14]

Culture Religion and Environment in Modern Society

As pointed out above, in modern society, use of the word "culture" is generally restricted to intellectual and artistic activity. Culture, religion, systems of governance, science and economics are all distinct realms of human activity. Culture is no longer directly related to the environment, nor does it include religion and governance systems.

The historical severance of culture, religion and environment coincided with increasing human mobility. As European societies developed colonial empires and were able to exploit resources from ever widening areas, their own place-specific knowledge was of less immediate relevance. They were able to distance themselves from the natural world. Indigenous, environmentally-based cultures of other continents presented barriers to expansion. Modern Christianity, science and economics developed in the context of this new human mobility and conquest. They were not considered to be place-specific, but assumed a universality over all people and places.

Traditional Christian doctrines which emphasised the distinction between creator and creation provided the theological basis for desacralising the natural world. The biblical

[7]Professor Eugene Hillman, cited in: "First Maasai Conference on Culture and Development, The Setting of the Maasai Community of Tanzania", Report of a Conference in Arusha, Tanzania, 1991, p.15.

[8]Williams, op. cit., p. 30.

[9]The dictionary definition of "indigenous" is "occurring or living naturally in an area; not introduced; native.

[10]Kenneth Ruddle, "The Transmission of Traditional Ecological Knowledge", in: Inglis, op. cit., p.19.

[11]Williams, op. cit., pp. 34–35.

[12]Nancy C. Doubleday, "Finding Common Ground: Natural Law and Collective Wisdom", in: Inglis, op.cit., p. 49.

[13]IDRC Reports, April 1993, p.14.

[14]Martha Johnson, in IDRC Reports, April 1993, p. 11.

concept of dominion of humans over nature sanctioned the exploitation of the environment for exclusively human ends. Thus Christian teachings provided the moral legitimacy for human ascendancy over nature, which became the accepted goal of human endeavour. Christian teachings made it possible for the budding sciences to study and manipulate the natural world. "The dominant religious tradition had no truck with that 'veneration' of nature... recognised as 'a discouraging impediment to the empire of man over the inferior creatures' ".[15]

The views of Bacon, Descartes and Hobbes are cited in accounts of the transition from holistic to mechanistic, individualistic world view. English philosopher Francis Bacon (1561–1626) maintained that all creation had meaning only in relation to humanity: "Man, if we look to final causes, may be regarded as the centre of the world insomuch that if man were taken away from the world, the rest would seem to be all astray, without aim or purpose".[16] Bacon viewed the Earth as a fertile gift ready to be unlocked and exploited by the scientific tapping of its physical and chemical dynamics. The conquest of nature by science was the route to the age of progress.[17]

The Frenchman, Rene Descartes (1596–1650), wrote that the world is like a giant, inanimate machine, where everything works mechanically according to mathematical necessities. Nature is inanimate with no inherent value of its own. Value is measured purely in terms of utility for humans. There are no moral inhibitions against the unlimited exploitation of nature.[18]

Another 17th century thinker, Thomas Hobbes (1588–1679), believed in the supremacy of individual interests over common interests. He viewed human life as a "short, nasty, brutish affair" and argued that human nature is such that every individual is always fighting others in order to gain advantage over them.[19] For Hobbes, there should be no shared resources. Privatisation of all resources is the only way to reduce fighting.

The work of these three thinkers and of the physicist Sir Isaac Newton (1642–1727) formed the backdrop for the emergence of modern economics. The English economist Adam Smith (1723–1790) was convinced that economic life was controlled by objective laws, just as Newtonian physics described the laws of nature.[20] Thus economics as an emerging academic discipline fashioned its approaches on the reductionist model of classical physics, concentrating only on that which is measurable. "Laws and models, once articulated, are then viewed as objective and unchanging... The dynamic interrelatedness of humans and the Earth has been dismissed as a relatively unimportant 'externality' ".[21]

Adam Smith believed that the economic freedom of people in self-interested pursuit would automatically contribute to the common good. A person's only responsibility to society was to look after their own individual self-interest. Ethics was replaced by economics. The church was delegated to "picking up the pieces from the new economic order", e.g. caring for the growing body of poor. The church was expected to provide charity for the victims of the changing economy. This pattern has continued down to the present age.[22]

The emergence of modern economics, with the accompanying separation of religion from science and economics paved the way for the Industrial Revolution, which is now held chiefly responsible for human-induced global climate change. At this workshop, we are seeking ways to address the problem of climate change and to formulate effective response strategies. Discussion of the world view that is responsible for our present predicament is not academic to that task.

There is a debate in the Inter-governmental Panel on Climate Change (IPCC) Working Group III (WG III) between setting targets for emissions reductions on the basis of ecological limits vs cost-benefit analysis. The economists who promote the use of cost-benefit analysis for the setting of targets are firmly grounded in the individualistic, mechanistic thinking of the European philosophers and economists described above. They believe that economic growth based on ever increasing flow-through of resources is the basic indicator of economic success, and that a price tag can be attached to everything, including human lives. This in itself is morally unacceptable, but to make matters worse, a life in Europe and North America is assumed to be worth more than a life in Africa. This kind of thinking is largely responsible for climate change in the first place, and is therefore unlikely to lead us to sound solutions. It must be examined,

[15] Keith Thomas. 1983. *Man and the Natural World: Changing Attitudes in English 1500–1800*. Allen Lane, London, p. 22. Cited in David Hallman. 1992. *A Place in Creation: Ecological Visions in Science Religion and Economics*. United Church Publishing House, Toronto. p. 187.

[16] Thomas, op. cit., p. 18, cited in Hallman, op. cit., p. 187.

[17] Hallman, op. cit., p. 202.

[18] Rupert Sheldrake, *The Rebirth of Nature. The Greening of Science and God*, Bantam Books, New York, 1992. p. 49.

[19] Cited in: Oduor Ong'wen, "Land for Profit or Survival: The Dilemma for ASAL Communities", in: *EcoNews Africa*, Vol. 2, No. 16, 18 November 1993. p. 2.

[20] Hallman, op. cit., p. 202.

[21] Hallman, ibid., p. 206.

[22] Hallman, ibid., p. 195. In developing countries, NGOs have now been designated the task of "putting a human face" on structural adjustment.

rejected, and replaced by a world view more friendly to people and the environment.

Challenges to the Economistic World View

Despite its undeniable successes, many people are challenging the modern economic system and its underlying mechanistic/individualistic world view. The economists who wish to set targets according to cost-benefit analysis have been challenged within IPCC WG III itself. This workshop on equity and social considerations is apparently a result of that challenge.

A major factor in the challenge to the mechanistic/individualistic world view is the appearance of the global environmental problems of climate change and depletion of the ozone layer. These problems manifest the limited carrying capacity of the Earth and the inter-connectedness of all things. They also demonstrate a basic flaw of the market system. In the theoretically self-regulating market system, scarcity should lead to higher prices and promote conservation. In reality, however, the market is short-sighted and future shortages do not affect current prices. Given the now evident environmental limitations, sustainable growth is a contradiction in terms.[23] Unlimited growth is impossible and material expansion cannot continue to be the aim of economic life.

New thinking in science and theology also challenges the mechanistic, individualistic assumptions of modern economics and approaches the kind of holistic, spiritualistic thinking that is found among indigenous peoples. In science, quantum physics and chaos theory question the mechanistic foundations of Newtonian physics. According to chaos theory, elements are in constant communication with each other in the transition processes between different states of being. The universe is characterised by omnipresent feedback within and between systems, both over space and over time.[24] Even very small actions can have profound effects far from their initial source. Even such seemingly polar opposites as order and chaos in the universe are actually interrelated.[25]

In process theology, the whole of creation is infused with God and God is infused with the whole. God is totally integrated with life. God is no longer detached, transcendent, omnipotent. The ongoing creative process, including our own human development, occurs through sensitive interactions with the world. The action-response model pervades life in its movement towards ever greater wholeness. To understand the nature of our world, we must recognise the importance of this organic inter-relatedness.[26]

Feminist theology has also contributed towards an integration of environmental and religious concepts. Concepts of God as Mother promote a deeper understanding of God's role as the Creator and sustainer of life. God as Mother emphasises ecological justice, where the gifts of life must be shared by all and not hoarded by the few that are rich.[27]

The concept of God as Mother is not alien to indigenous cultures. Enkai, the God of the Maasai, is neither male nor female, although the gender of this word is feminine. God is addressed more often than not in the feminine gender, probably in recognition of the originating source of life and the tender nurturing that life requires.[28]

The growing role of Southerners in the global debate constitutes another major challenge to the economistic world view. Southerners have first hand experience of the failures of modern economics. As the deleterious effects of economic liberalisation and privatisation become more evident, they are understandably skeptical of claims that more for the rich will eventually also mean more for the poor. Many Southerners now involved in international dialogue still have close ties to their indigenous cultures and are likely to espouse an organic world view in which all of nature is endowed with spirit and belongs to an inter-connected whole. In this organic system of thinking, every part of the system has intrinsic value and damage to any part will affect the whole. The environmental problems we face, including global climate change, are the inevitable results of human violation of nature.

Southerners are also likely to have a stronger sense of community. Although this sense of community is being rapidly eroded by Northern culture, it still generally outweighs the pursuit of individual self-interest. There is a growing body of scientific work, particularly on indigenous knowledge and land tenure issues, that recognises the importance of indigenous resource management strategies and organisational structures. The theory of the "tragedy of the commons" has been refuted and communal forms of land management are now recognised as ecologically sound, efficient, productive land management systems. An example is the pastoralist system of the Maasai of Kenya and Tanzania. Conservationist Henry Fosbrooke,

[23]"Sustainable Growth—A Contradiction in Terms?", Report of the Visser 't Hooft Memorial consultation, The Ecumenical Institute, Chateau de Bossey, Switzerland, Pre-Publication Edition, 1993. p. 30.

[24]Hallman, op. cit., p. 58.

[25]Hallman, Ibid. p. 9.

[26]Hallman, Ibid., p. 77f.

[27]Hallman, Ibid., p. 79.

[28]Hallman, op. cit., p. 15.

when asked what would be the best way to both conserve and make productive use of the arid and semi-arid lands of the Great Rift Valley, said the entire area should be turned back to the Maasai to manage under their traditional systems.[29]

Unless issues are addressed from the perspective of an integrated world view that incorporates ethical concerns of social justice and environmental integrity, we cannot adequately address the problem of climate change. Luckily, things are changing. The convergence of the different factors mentioned above—global environmental crisis, new scientific and theological teachings, and a greater voice for Third World peoples in the international arena—are putting pressure on Northern societies to re-examine their world view. A major effort in this direction is the recent published study paper of the World Council of Churches.

WCC Document: A Reintegration of Culture, Religion and Environment

To address the issue of climate change in the context of the Christian faith, the World Council of Churches assembled a team of people from all continents and organised a series of regional and international workshops. The outcome is a WCC Study Paper entitled: "Accelerated Climate Change: Sign of Peril, Test of Faith".[30] The Study Paper is meant to provide a foundation for discussion and action on climate change within member churches around the world.

The Study Paper acknowledges that human activity is altering the conditions for life on Earth through the emission of polluting "greenhouse" gases. In seeking responses, the Study Paper challenges the economic system predicated on unlimited growth that is the root of the current ecological crisis, and recognises the important contribution of indigenous cultures to sustainable environmental management.

The Study Paper affirms the intrinsic worth and integrity of all humans and the inherent worth of the natural world independent of its instrumental value. It supports an economy based on respect for ecological integrity and the satisfaction of basic human needs and rejects excessive consumption and the economic concept of unlimited growth. It recognises that responsible transformation of society requires full recognition of human rights and equitable distribution of decision-making power throughout society.

The Study Paper calls for the setting of targets in line with the objective of the United Nations Framework Convention on Climate Change (UN-FCCC). Industrialised nations must bring their GHG emissions down to a level that will not present a dangerous interference with global climate systems. Developing nations must define new models of development that take into account ecological limits posed by the threat of accelerated climate change.

But the WCC document goes beyond the UN-FCCC. It concludes that targets cannot be reached within the existing economic system based on an axiom of infinite growth. The problems of climate change and ozone depletion show that unlimited growth is manifestly impossible. Simply using resources more efficiently is not the answer. In a world of ever-expanding material production and consumption, more efficient use of resources only delays the inevitable. "While producing more efficient automobiles is an important step, all reductions in petroleum consumption will eventually be cancelled out if the total number of automobiles continues to rise" (p.23).

However, as soon as we recognise the environmental limits to growth, we face tough moral decisions of equity. If there is not enough for everyone's greed and everyone's need, priority must be given to need. Over-consumption by the rich is reflected directly in impoverishment of the poor... In the words of Charles Birch at the Nairobi Assembly of the WCC (1975), 'the rich must live more simply that the poor may simply live' " (p. 23).

Despite formidable obstacles to change, the Study Paper provides a framework and some suggestions on how to move forward, beginning with a vision of community: "Reducing the threat of climate change requires fundamental changes in the way that people relate to each other and the Earth. It requires changes that build community" (p.25). The Study Paper calls for a transformation of economic structures and processes to build the kind of community envisioned.

The Study Paper recognises the need for collaboration with other non-Christian groups. It recognises the movement of God's Spirit beyond the Christian churches, in many religions and cultures. Dubbed the "Melchizedek factor" because Abraham recognised the presence of God's spirit in Melchizedek who did not belong to the people of the covenant (Gen. 14:17–20), this principle translates into an imperative to learn from the traditional wisdom and spirituality of indigenous peoples around the world who have lived in integrity with creation through the centuries.

The inclusion in the WCC paper of the concept of "building community" as the central role of economics, and of the "Melchizedek factor", are due in large part to arguments put forth by the African participants and supported by other Southern delegates.

[29] Personal communication.

[30] "Accelerated Climate Change: Sign of Peril, Test of Faith", A Study Paper from the World Council of Churches. 1994. Geneva.

The Study Paper raises a number of ethical questions relevant to our daily lives. Among these are the role of industry and transnational corporations (TNCs), mobility and transportation, the military, deforestation, agriculture, desertification and population growth.

TNCs are directly responsible for 50% of all GHG emissions. Profoundly ethical concerns lie behind the question of whether the role of TNCs can be made compatible with the care of the Earth. Military activity and related space programmes are also major emitters of GHGs and chemicals that deplete the ozone layer.

Forests also play an important role, but it is inconsistent to maintain that Southern forests are to be managed as a global commons, while the other great carbon reservoir, unmined petroleum, is managed as a national or private resource. On the issue of population growth, the Study Paper points out that most of the increase in GHG emissions results from over-consumption by individuals in the North, not from population growth in the South. However, since global resources are limited, it is clear that unlimited population growth poses a burden on the Earth's resources. Population policy based on education and improved quality of life must be an integral part of efforts to achieve sustainable development.

Finally, the Study Paper offers a number of theological considerations. Among these is the recognition that a misinterpretation of Genesis has contributed to modern culture's propensity to devalue women and mistreat natural systems. Christians are encouraged to think of God as Mother as well as Father.

Summary and Conclusion

This paper argues that indigenous cultures, because they depend for their survival on the environments in which they live, have developed integrated systems for sustainable resource management. The inter-dependency and intrinsic value of all being is recognised, the world is imbued with spirit, and religion is an integral part of these cultures.

As European society became mobile and undertook its conquest of the globe, it became less dependent on local environments for its survival. The drive to conquest was aided and abetted by the Christian theological teachings of separation of creator and creation, and of dominion of man over women and nature. Seventeenth Century philosophers taught that the world was an inanimate machine created solely for the use of humans and with no intrinsic value of its own. Human nature was basically selfish and the best way to organise society was to promote the achievement of individual gain.

These mechanistic, individualistic ideas formed the basis of economic theory and practice that led to the Industrial Revolution, which in turn is mainly responsible for the crisis of climate change we face today. The economic theory that brought us the present crisis still largely determines the behaviour of Northern societies.

The crisis of climate change brings us face to face with the realisation that the global environment is the local environment, with the knowledge of the shamans that action upon the environment always begets reaction. The limits of local environments that were recognised and respected by indigenous people have now become the limits of the global environment, to be incorporated into global resource management systems.

New thinking in the physical and social sciences and in theology is moving us towards a more organic view of reality, not unlike that of indigenous cultures. Economics has shown itself to be the most conservative of disciplines. It is lagging behind the other disciplines and must be brought to a re-examination of its own assumptions about physical and social reality. The WCC document calls economics to task, insisting that it recognise ecological limits and become subservient to the task of building community.

Equity is an important part of building community. It is significant that once ecological limits are recognised and unlimited growth is no longer possible distributive justice comes into play. This is an ethical issue, outside the realm of economics. It belongs to the realm of religion.

We are still a long way from the goal of an economics subservient to the task of building community. Despite ample empirical evidence that they do not represent reality, the "myths" behind modern economics and global conquest still dominate development thinking. The doctrine of the "tragedy of the commons" is still believed and privatisation is gospel. Those who maintain that resources should be collectively managed for the common good are dismissed as "idealists". Indigenous societies with their profound knowledge of local environments and systems of sustainable resource management, are considered quaint and outdated. It is common to hear people say, of the Maasai for example, that they should give up their way of life and join the modern world.

In the South, great harm has been done and continues to be done by development agents and missionaries who impose Northern concepts and organisational structures on indigenous cultures. Missionaries continue to sow confusion in indigenous societies by rejecting their traditional beliefs, thereby undermining their entire cultural heritage.

As governments privatise land and replace traditional systems of governance with new forms of political representation, important forms of resource management are lost. The shamans, the Maasai elders, the women, and others who know the best ways to sustainably exploit resources are unrepresented in the new systems of elected officials, or at the tables of development agents who make plans for the exploitation of their lands.

In the North and in the South, economists hope to solve environmental problems by including in their calculations the "cost" of environmental degradation and trusting in the "invisible hand" of the market.

This is the stuff of which development is made today. It is completely at odds with emerging theological and scientific theories. It is time for economics to catch up.

Intergenerational Equity

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Intergenerational Equity: Toward an International Legal Framework[1]

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Introduction

Sustainable development rests on a commitment to equity with future generations. This ethical and philosophical commitment constrains the inclination to take advantage of our temporary control over the earth's resources in order to use them for our own benefit without careful regard for what we leave for our children or for their descendants.

It is useful to address the issue of sustainability through law and philosophy in addition to economics. Concerns about equity are central in the legal tradition. Law and philosophy provide a basis for analysing the normative relationship among generations and the instruments for transforming normative values into rights and obligations. Legal instruments provide a means for ensuring that those who hold power follow the ideals of justice held by society. (While there are different schools of jurisprudence, it is not necessary to differentiate them here.)

Sustainability, which implies intergenerational fairness, is possible if we look at the earth and its resources not only as an investment opportunity but as a trust, passed to us by our ancestors, to be enjoyed and passed on to our descendants for their use.[2] Such a "planetary trust" conveys to us both rights and responsibilities. Most important, it implies that future generations, too, have rights, although these rights have meaning only if we, the living, respect them and if this respect transcends the differences among states, religions, and cultures.[3] The notion that each generation holds the earth as a steward or in trust for its descendants strikes a deep chord with men and women of all cultures, religions, and nationalities. Nearly all human traditions recognise that we, the living, are but sojourners on earth and temporary stewards of its resources.

The theory of intergenerational equity proposed argues that we, the human species, hold the natural environment of our planet in common with all members of our species: past generations, the present generation, and future generations (Weiss, 1989). As members of the present generation, we hold the earth in trust for future generations. At the same time, we are beneficiaries entitled to use and benefit from it.[4]

There are two relationships that must shape any theory of intergenerational equity in the context of our natural environment: our relationship to *other generations* of our own species and our relationship to the *natural system* of which we are a part. The human species is integrally linked with other parts of the natural system; we affect and are affected by what happens in the system. We alone among all living creatures have the capacity to shape significantly our relationship to the environment. We can use it on a sustainable basis, or we can degrade environmental quality and deplete the natural resource base. As the most sentient of living creatures, we have a special responsibility to care for the planet.

[1]From: *Global Accord: Environmental Challenges and International Responses*, edited by Nazli Choucri, MIT Press, Cambridge, 1993, pp. 333–53. We are grateful Dr Weiss availed this paper for the Proceedings.

[2]Some scholars, such as J. Simon (1981), would contend that the concern with future generations is misplaced because technological innovation and infinite resource substitution will ensure the well-being of future generations. However, while improvements in technology and the availability of substitute resources may offset some exhaustion of natural resources, the possibility of real price increases in natural resources to future generations remains. Moreover, our activities pose long-term risks to the health of our planet and, arguably, to our cultural resources. We have no right to assume that technical advances will clean up any mess that we make. There are many examples of people with abundant land resources who reduced a region to desert by misuse, such as by excessive cultivation, and then moved on.

[3]This chapter sets forth a theory of intergenerational equity that finds resonance in international legal instruments. There are other approaches to intergenerational equity that are not covered here. For analysis of these, see chapter 11 in this book by J. Rothenberg, and Weiss, 1989.

[4]The theory also applies to cultural resources, since they form an integral part of the legacy we give to future generations and are linked to our role as a member of the natural system. For application of the theory of intergenerational equity to cultural resources, see Weiss, 1989.

The second fundamental relationship is that between different generations of the human species.[5] All generations are inherently linked to other generations, past and future, in using the common patrimony of the earth.[6] The theory of intergenerational equity stipulates that all generations have an equal place in relation to the natural system. There is no basis for preferring the present generation over future generations in their use of the planet. This assumption finds deep roots in international law. The preamble to the Universal Declaration of Human Rights begins, "Whereas recognition of the inherent dignity and of the equal and inalienable rights of all members of the human family is the foundation of freedom, justice and peace in the world..." The reference to all members of the human family has a temporal dimension that brings all generations within its scope. The reference to equal and inalienable rights affirms the basic equality of such generations in the human family.

Each generation can and should use the natural system to improve the human condition. Improvements should be conserved for future generations. If one generation degrades the environment severely, however, it will have violated its intergenerational obligations relating to the care of the natural system. In such cases, other generations may have an obligation to restore the robustness of the system, with costs distributed across generations. The anchor of a legal framework is thus the notion of equality as the norm connecting sequential generations in their use and care of the environment. The corollary is the concept of *partnership* between humans and nature and between sequences of humans born.

To define intergenerational equity, it is useful to view the human community as a partnership among all generations. In describing a state as a partnership, Edmund Burke (1790, p. 140) observed that "as the ends of such a partnership cannot be obtained in many generations, it becomes a partnership not only between those who are living but between those who are living, those who are dead, and those who are to be born". The purpose of human society must be to realise and protect the welfare and well-being of every generation in relation to the planet. This requires sustaining the life-support systems of the planet as well as the ecological processes and the environmental conditions necessary for a healthy and decent human environment (IUCN, 1980).

In this partnership, no generation knows beforehand when it will be the living generation, how many members it will have, or even how many generations there will ultimately be. It is useful, then, to take the perspective of a generation that is placed somewhere along the spectrum of time, but does not know in advance where it will be located (Rawls, 1971).[7] Such a generation would want to inherit the earth in at least as good condition as it has been in for any previous generation and to have as good access to it as previous generations have had. This requires each generation to pass the planet on in no worse condition than that in which it received it and to provide equitable access to its resources and benefits. Each generation is thus both a trustee for the planet with obligations to care for it and a beneficiary with rights to use it.

While intergenerational equity may be viewed as in conflict with achieving intragenerational equity, the two are consistent and in fact must go together. Members of the present generation have an intergenerational right of equitable access to use and benefit from the planet's resources, which derives from the underlying equality which all generations have with each other in relation to their use of the natural system. Moreover, even the most selfish members of the present generation who care only about their own descendants must, as they extend their time horizon further, increasingly care about the general environment that their descendants will inherit. Since no one country or group of countries alone has the power to ensure a healthy environment, all must cooperate to ensure a robust planet in the future. This means meeting the basic needs of the poor so that they will have

[5]An anonymous reviewer thoughtfully noted that this assumes that humans share the belief that they are part of a "species being". It may be argued that some social groups deny that human beings share a single destiny, such as those who proffer explicitly racial doctrines or those who espouse social Darwinism and believe that human evolution will lead to further differentiation of species and to the disappearance of "backward" elements. However, the fact that humans themselves try to differentiate among themselves or to use theories of evolution to advance their own ends does not alter the fact that all humans are part of the natural system and, as such, are inherently linked with those who went before and those who come after in using and caring for it.

[6]The theory has been criticised for depending upon a link with improving the human condition and hence being anthropocentric rather than on a moral level with nature itself. See D'Amato 1990, p. 190. While the theory is concerned with equity among generations in the care and use of the planet, it is explicitly rooted in the recognition that the human species is part of the natural system. This implies great respect for the natural system of which we are a part, but it does not imply that all other living creatures are or should be treated equally. Rather, the human species, as a part of this natural system, has a special obligation to maintain the integrity of the planet so that all generations of humans will be able to enjoy its fruits.

[7]Some human communities may, however, contend that they know the final days of existence are approaching and hence that they or certain elites within them have extraordinary rights over the environment. The veil of ignorance is only an analytical tool to facilitate the derivation of principles of intergenerational equity; it does not by itself regulate the behaviour of communities. Nor need the assumption be accepted by all communities in order for normative principles to develop that would be intended to guide community behaviour, including theirs. O. Young, in Chapter 13 of this book, suggests that maximising uncertainty may be a more effective way to convince the present generation to consider the future than to ask that they imagine themselves in a veil of ignorance. But whatever the merits of this approach, which arguably may cut against positive actions to protect the environment for future generations as well as in favour of such actions, it does not offer a premise from which to derive principles of intergenerational equity.

both the desire and ability to fulfil their intergenerational obligations to conserve the planet.

To be sure, there are instances where the actions needed to protect the health of the planet for future generations may conflict with the immediate alleviation of poverty, although poverty itself is a primary cause of ecological degradation. In these instances, we need to develop processes for ensuring that the rights of future generations are adequately protected while at the same time addressing poverty as quickly and effectively as possible through appropriate mechanisms.

Foundations of the Theory of Intergenerational Equity

Three distinct foundations provide a robust basis for this legal perspective on equity among generations: (1) philosophical and legal traditions, (2) international law roots, and (3) institutional foundations.

Philosophical and Legal Traditions

Philosophers from diverse cultural traditions have recognised that we are trustees or stewards of the natural environment. This fundamental thesis is also deeply rooted in the legal traditions of the international community. These roots can be found in the common and civil law traditions, in Islamic law, in African customary law, and in Asian nontheistic traditions.

The proposed theory of intergenerational equity finds deep roots in the Islamic attitude toward the relation between humans and nature. Islamic law regards man as having inherited "all resources of life and nature" and having certain religious duties to God in using them. Each generation is entitled to use the resources, but must care for them and pass them to future generations.

> The utilization and sustainable use of these resources is, in Islam, the right and privilege of all people. Hence, man should take every precaution to ensure the interests and rights of all others since they are equal partners on earth. Similarly, he should not regard such ownership and such use as restricted to one generation above all other generations. It is rather a joint ownership in which each generation uses and makes the best use of nature, according to its need, without disrupting or upsetting the interests of future generations. (IUCN and Saudi Arabia 1983, p. 13).

Islamic law supports collective restrictions, which are to be observed under a principle of good faith, and collective rights, which are rights of the community of believers as a whole (Khadduri, 1984, pp. 137–39, pp. 219–20, pp. 233–39).

In the Judeo-Christian tradition, God gave the Earth to the people he created and to their offspring as an everlasting possession, to be cared for and passed on to each successive generation (Genesis 1:1–31, 17:7–8). This tradition has been carried forward in both the common law and the civil law traditions. The English philosopher John Locke (1690), for example, asserts that, whether by the dictates of natural reason or by God's gift "to Adam and his posterity", mankind holds the world in common. In the civil law tradition, this recognition of the community interest in natural property appears in Germany in the form of social obligations that are inherent in the ownership of private property (Dolzer, 1976).

The socialist legal tradition also has roots which recognise that we are only stewards of the earth. Karl Marx, for example, states that all communities, even if taken together, are only possessors or users of the earth, not owners, with obligations to protect and improve it for posterity (Ross and Silk, 1987, p. 67).

According to African customary law we are only tenants on earth, with obligations to past and future generations (Allott, 1975, p. 70). Under the principles of customary land law in Ghana, land is owned by a community that goes on from one generation to the next. A distinguished Ghanaian chief said, "I conceive that land belongs to a vast family of whom many are dead, a few are living, and countless host are still unborn" (Ollennu, 1962, p. 4). The nontheistic traditions of Asia and South Asia, such as Shinto, also stress a respect for nature and our responsibilities to future generations as stewards of this planet. In most instances they call for living in harmony with nature (Stewart-Smith, 1987; Northrop, 1949).

International Law

The theory of intergenerational equity has a deep basis in international law (Weiss, 1989, p. 25–26). The United Nations Charter, the preamble to the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, the Convention on the Prevention and Punishment of the Crime of Genocide, the American Declaration on the Rights and Duties of Man, the Declaration on the Elimination of Discrimination against Women, the Declaration on the Rights of the Child, and many other human rights documents reveal a fundamental belief in the dignity of all members of human society and in an equality of rights that extends in time as well as space. Indeed, if we were to license the present generation to exploit our natural and cultural resources at the expense of the well-being of future generations, we would contradict the purposes of the United Nations Charter and international human rights documents.

Since World War II, states have begun to express concern in international legal instruments for the welfare of future generations and to set forth principles or obligations that are intended to protect and enhance the welfare of both present and future generations. Even the United Nations Charter, drafted in the aftermath of World War II, affirmed the universal concern for the welfare of future generations in its opening paragraph: "We the peoples of the United Nations, determined to save succeeding generations from the scourge of war..." (United Nations Charter, 26 June 1945, 59 Stat. 1031).

Concern for justice to future generations regarding the natural environment first emerged in the preparatory meetings for the 1972 Stockholm Conference on the Human Environment. The preamble to the Stockholm Declaration on the Human Environment expressly refers to the objective of protecting the well-being of future generations: "To defend and improve the environment for present and future generations has become an imperative goal for mankind". The concept of protecting the natural environment for future generations was explicitly incorporated in the language of three treaties negotiated more or less contemporaneously with the Stockholm Declaration: the 1972 London Ocean Dumping Convention, the 1973 Convention on International Trade in Endangered Species, and the 1972 Convention Concerning the Protection of the World Cultural and Natural Heritage. The regional seas conventions which were subsequently negotiated under the United Nations Environment Programme (UNEP) carried forward this concern for future generations. Other international agreements of the last two decades have contained language indicating either a concern for the sustainable use of the environment or a concern for future generations, ofttimes by reference to the common heritage of mankind (Weiss, 1984, p. 495; pp. 540–63). The 1982 United Nations World Charter for Nature, while not a binding agreement, explicitly refers to a requirement to protect species and ecosystems for future generations.

Except for the above references to future generations, international law to date has addressed intertemporal issues primarily in the context of relating the present to the past. In public international law, an intertemporal doctrine applies to territorial claims, to certain other rules of customary international law, and to several aspects of treaties. In private international law, it is reflected in questions of choice of time, as in conflict-of-law rules. In public international law, Judge Huber enunciated the intertemporal doctrine in the classic *Island of Palmas Arbitration*,[8] which involved a dispute between the United States and the Netherlands over the sovereignty of the small Pacific island. As described by Judge Huber, the doctrine has two elements: that acts should be judged in light of the law at the time of their creation, and that rights acquired in a valid manner may be lost if they are not maintained in a manner consistent with the changes in international law.

Although most disputes raising the intertemporal doctrine have involved territorial claims, the doctrine is more broadly applicable to other issues in customary international law and to treaties. There are several intertemporal issues raised by treaties: the proper interpretation of a treaty over time, the continuing validity of a treaty in the face of changed circumstances, and retroactive application. The Vienna Convention on the Law of Treaties contains specific provisions addressing these issues, although the doctrine of intertemporal law is not explicitly mentioned. Customary international law doctrines, such as *pacta sunt servanda* and *rebus sic stantibus*, respond to the intertemporal question of the continuing validity of treaties.

Intertemporal issues also arise in the context of procedural rules set by international tribunals and in private international law. They arise primarily as conflicts in time of rules of private international law adopted in a particular country, conflicts in time of rules of intertemporal law of the *lex fori* and *lex causae*, and conflicts of time and space caused by changes in the connecting factor. In the late 1970s, l'Institut de Droit International undertook a comprehensive study of intertemporal problems in private international law, and in 1981 it adopted a resolution setting forth applicable rules to govern intertemporal problems in private international law (l'Instut de Droit International, 1982 and 1979; Graveson, 1979; Sorensen, 1973).

Intertemporal problems are common in national legal systems. Frequently they appear as conflict-of-law questions. The civil law tradition has a well-developed theory of conflict-of-law cases of intertemporal law, which invoke such distinctions as *intertemporal, droit transitoire,* and *conflit mobile,* terms which have no ready equivalents in English or the common law traditions. Temporal issues also arise in countries as tort liability cases. These cases involve claims that nuclear tests conducted for twenty or more

[8] *Island of Palmas Arbitration* (Netherlands vs US) 2 R. Int. Atb. Awards 831 (1928). The principle has been subsequently applied in a number of cases before the International Court of Justice, including the *Minquier and Ecrehos* case, the *Western Sahara* case, the *North Sea Continental Shelf* cases, and the *Aegean Sea Continental Shelf* case. While the first element of the intertemporal doctrine has been widely accepted as a basic principle, the second has been controversial.

[9] For example, 460 cancer and leukemia victims who were infants at the time the United States conducted nuclear tests in Utah and Nevada during the 1950s tried to recover for harm. Allen vs US, 527 Fed. Supp. 476 (D. Utah 1981). On 15 October 1990, a new law went into effect which established a $100 million trust fund to provide payment to persons believed harmed by fallout from nuclear testing at the Nevada test site (*New York Times*, 16 October 1990, p. 1, cols 4–5).

years caused subsequent cancers and leukemia in victims,[9] that harmful drugs taken by mothers produced harm to fetuses, or that exposure to toxic substances years previously caused subsequent cancers, other health problems, and environmental damage. Similar issues have arisen at the international level, as governments of Pacific islands have made claims against governments of countries with nuclear weapons for the contamination of their people and their environments by nuclear testing in the Pacific in the 1950s.

Institutional Foundations

The International Court of Justice has long invoked equitable principles in its jurisprudence.[10] There is a long tradition in international law of using principles of equity to interpret documents and reach decisions in order to achieve a just result (Lapidoth, 1987; Chattopadhyay, 1975). In the World Court's jurisprudence, as Sohn (1984, p. 303, p. 308) has noted, the court has clearly distinguished between principles of equity and equity *ex aequo et bono* under Art. 38(2) of the court's statute and between equitable principles in international law and equity in domestic law. In the *North Sea Continental Shelf* cases, the court sets forth the classic description of equity:

> Whatever the legal reasoning of a court of justice, its decisions must by definition be just, and therefore in that sense equitable. Nevertheless, when mention is made of a court dispensing justice or declaring the law, what is meant is that the decision finds its objective justification in considerations lying not outside but within the rules, and in this field it is precisely a rule of law that calls for the application of equitable principles.

Increasingly equity is being invoked to mean "equitable standards for the allocation and sharing of resources and benefits" (Henkin et al., 1986, p. 102. See also Thacher, 1987; Janis, 1983). The Law of the Sea Convention, for example, includes several provisions invoking equity. Article 59 provides that conflicts over the exclusive economic zone are to be "resolved in the light of equity". Agreements delimiting the exclusive economic zone between states and opposite or adjacent coasts must "achieve an equitable solution" based on international law. In addition, the International Law Commission's draft articles on the succession of states in respect to state property, archives, and debt repeatedly invoke "equitable proportions" and "equitable compensation" as the basis for allocating property between a predecessor and a successor state(s).

The use of equity to provide equitable standards for allocating and sharing resources and benefits lays the foundation for developing principles of intergenerational equity. These principles can build upon the increasing use by the International Court of Justice of equitable principles to achieve a result that the court views as fair and just. The World Bank, the International Monetary Fund, and the major international organs of the United Nations system are predicated on notions of equity among states. The concepts and the content differ, but the underlying precepts driving "development", "technical assistance", and more recently "sustainability" are ones of providing for present and future generations an acceptable quality of life. The 1992 United Nations Conference on Environment and Development (UNCED) focused on environmentally sustainable economic development, which is an inherently intergenerational issue.

The Theory of Intergenerational Equity: Legal Dimensions

The two crucial dimensions for the theory of intergenerational equity are time and space (in relation to the natural system). They are interconnected and cannot be separated, either conceptually or practically, even for purposes of international public policy.

Three Principles of Equity

Three principles frame intergenerational equity. First, each generation should be required to conserve the diversity of the natural and cultural resource base so that it does not unduly restrict the options available to future generations in solving their problems and satisfying their own values, and it should also be entitled to diversity comparable to that enjoyed by previous generations. This principle is called "conservation of options". It can be accomplished in part by technological innovation that creates substitutes for existing resources or processes for extracting and using them more efficiently.

Second, each generation should be required to maintain the quality of the planet so that it is passed on in no worse condition than that in which it was received, and it should also be entitled to planetary quality comparable to that enjoyed by previous generations. This is the principle of "conservation of quality". It does not mean that the environment either could or should remain largely unchanged; this would be inconsistent with the third principle below. Rather

[10]See in particular the maritime boundary decisions *North Sea Continental Shelf* cases (Federal Republic of Germany vs Denmark; Federal Republic of Germany vs Netherlands) 1969 ICJ 3; *Continental Shelf* case (Tunisia vs Libya) 1982 ICJ 18; the case *Concerning the Delimitation of Maritime Boundary of Gulf of Maine* (Canada vs US) 1984 IDJ 246; and *Continental Shelf* case (Libya vs Malta) 1985 ICJ 13.

it recognises that tradeoffs are inevitable and that a framework must be developed in which such balancing can take place. This will require the development of predictive indices of environmental quality, the establishment of baseline measurements, and an integrated monitoring network.

Third, each generation should provide its members with equitable rights of access to the legacy of past generations and should conserve this access for future generations. This is the principle of "conservation of access". It means that members of the present generation have a nondiscriminatory right to use the resources of the planet to improve their own economic and social well-being provided that they do not unreasonably interfere with the access of other members of their generation to do so as well.

Four criteria guide the development of principles of intergenerational equity. First, the principles should encourage equality among generations, neither authorising the present generation to exploit resources to the exclusion of future generations nor imposing unreasonable burdens on the present generation to meet indeterminate future needs. Second, they should not require one generation to predict the values of future generations. They must give future generations flexibility to achieve their goals according to their own values. Third, they should be reasonably clear in their application to foreseeable situations. Fourth, they should be generally shared by different cultural traditions and be generally acceptable to different economic and political systems.

The proposed principles recognise the right of each generation to use the earth's resources for its own benefit but constrain the actions of the present generation in doing so. Within these constraints they do not dictate how each generation should manage its resources, and they do not require that the present generation predict the preferences of future generations, which would be difficult if not impossible. Rather, they try to ensure a reasonably secure and flexible natural resource base for future generations, which they can use to satisfy their own values and preferences. The principles of options (diversity), quality, and access form the basis of a set of intergenerational obligations and rights, or planetary rights and obligations, that are held by each generation. These rights and obligations derive from each generation's position as part of the intertemporal entity of human society.

Rights and Obligations: Planetary Scope

Planetary intergenerational rights and obligations are integrally linked. The rights are always associated with obligations. They are rights of each generation to receive the planet in no worse condition than did the previous generation, to inherit comparable diversity in the natural and cultural resource bases, and to have equitable access to the use and benefits of the legacy. They represent in the first instance a moral protection of interests that must be transformed into legal rights and obligations.

In the intergenerational dimension, the generations to which the obligations are owed are future generations, while the generations with which the rights are linked are past generations. Thus, the rights of future generations are linked to the obligations of the present generation. In the intragenerational context, planetary obligations and rights exist between members of the present generation. They derive from the intergenerational relationship that each generation shares with those who have come before and those yet to come.

Intergenerational rights of necessity inhere in all generations, whether these be immediately successive generations or ones more distant. There is no theoretical basis for limiting such rights to immediately successive generations. If we were to do so, we would often provide little or no protection to more distant future generations. Nuclear and hazardous waste disposal, the loss of biological diversity, and ozone depletion, for example, have significant effects on the natural heritage of more distant generations.

Intergenerational planetary rights may be regarded as group rights, as distinct from individual rights, in the sense that generations hold these rights as groups in relation to other generations—past, present and future. They exist regardless of the number and identity of individuals making up each generation. When held by members of the present generation, they may acquire attributes of individual rights in the sense that they are identifiable interests of the individuals that the rights protect. However, those interests derive from the fact that those living now are members of the present generation and have rights in relation to other generations to use and benefit from the planet. The remedies for violations of these rights will benefit other members of the generation, not only the individual.[11]

Enforcement of these intergenerational rights is appropriately accomplished by a guardian or

[11]The temporal dimension may offer a theoretical basis for unifying those human rights that we now consider to be group or social rights and for so-called "new" human rights. Group rights, such as cultural rights, have a temporal dimension since the community inherently extends over time. Theoretically, rights to development, to health, and to the environment can be seen as intergenerational or intertemporal in that they are rights of access of each generation to use and benefit from our natural and cultural resources.

representative of future generations as a group, not of future individuals, who are of necessity indeterminate. While the holder of the right may lack the capacity to bring grievances forward and hence depends upon the representative's decision to do so, this inability does not affect the existence of the right or the obligation associated with it.

The question arises whether future generations can have rights. According to this argument, rights can exist only when there are identifiable interests to protect. This would require that we identify individuals who have interests to protect. Since we cannot know who the individuals will be in future generations until they are born, or even how many will exist, they cannot, according to this argument, have rights. But the rights of future generations are not individual rights; rather, they are generational rights in which the interests protected do not depend upon knowing the number or kinds of individuals that may exist in any given future generation.

It can be argued that such rights depend upon knowing at least the number of individuals in the future because if the earth's population continues to grow rapidly, the amount of diversity and the degree of quality that must be passed on will be higher than if the population in the future were at the same level or less than it is today. But, if anything, the existence of these generational rights to the planet may constrain the population policies of present and future generations. Whether a generation chooses to meet its obligations by curtailing exploitation, consumption, and waste or by constraining population growth is a decision it must make. The fact that future generations have a generational right to receive the planet in a certain condition puts constraints on the extent to which a present generation can ignore this choice.

Almost every policy decision of government and business affects the composition of future generations, whether or not these decisions are taken to ensure their rights under the principles developed above. Decisions regarding war and peace, economic policy, the relative prosperity of different regions and social groups, transportation, health, and education—all influence the demographics and the composition of future generations by affecting the lives and fortunes of the present generation: Who will succeed and prosper, who will marry whom, who will have children, and even who will emigrate (Weiss, 1990).

Our planetary obligations to future generations are owed to all the earth's future human inhabitants, whomever they may be. This opens the possibility that all decisions deserve to be scrutinised from the point of view of their impact on future generations. This may lead to further development of human rights law as a useful and broadly acceptable theoretical underpinning to sustainable resource development. The possibility that intergenerational equity may place limits on our actions is an important new area of human rights research.

Such limitations should be applied very narrowly so that the rights of future generations do not develop into an all-purpose club to beat down proposals for change. But long-term environmental damage is a good place to begin. Future generations have the right to be assured that we will not significantly pollute groundwater, load lake bottoms with toxic wastes, extinguish important habitats and species, or change the world's climate dramatically—all long-term effects that are difficult or impossible to reverse—unless there are extremely compelling reasons to do so that go beyond profitability (Weiss, 1990).

There may be key breaking points in our global environmental system beyond which systems will reorganise and substantially change their properties.[12] If we are concerned about future generations, it is important to try to predict these breaking points. More important, the best tool that we could give future generations with which to respond to abrupt changes and reorganisations is a robust planet, which requires conserving a diversity of resources so that future generations have greater flexibility in designing responses.

In chapter 11 of this book, Rothenberg criticises the planetary trust theory as idealistic and requiring additional assumptions to accommodate intragenerational equity. In its place, he proposes a model of backward indebtedness. According to this construct, members of the present generation owe a debt to their predecessors in previous generations, which they pay to their successors in the form of investments, over and above those they would make in their own interest, in the robustness and sustainability of the planet. These debts are owed separately by each member of the present generation, but are owed to the successor generations taken collectively. In general, the backward debt is used to pay for the same kind of activities that are obligated by the planetary trust—pollution abatement, development of new resources, etc. An important difference is that irreversible change that threatens the robustness of the planet or depletes resource options is discouraged by insurance premiums rather than by normative rules and procedures.

As Rothenberg points out, both the backward indebtedness and the planetary trust models

[12]This is consistent with the scientific paradigms expressed in the theories of catastrophe and of the dynamics of complex systems far from equilibrium. For catastrophe theory, see Thom, 1983; for the theory of complex systems, see Prigogine and Stengers, 1984.

constrain present consumption so as to ensure the welfare of future generations. In the backward indebtedness model, the obligations of the present generation flow directly from the benefits they have received rather than from a normative structure of stewardship and equality among generations. In the planetary trust model, intragenerational equity flows not from backward indebtedness, but from the nondiscriminatory access rights of each generation to natural (and cultural) resources.

The backward indebtedness model has the major disadvantage that the obligation on the present generation to conserve resources (to engage in proper resource accounting in making investment decisions) is an extra assumption that is external to the model. It assumes that generations are grateful for their legacy, just as children are grateful to their parents, and will sacrifice for unknown generations even though the past generations are not there to hold them accountable in any way.

Implementation Strategies

Elsewhere I have proposed eight strategies for implementing intergenerational equity.[13] Four of these are stressed here: the representation of future generations in decision-making processes, including those in the marketplace; intergenerational assessments of the impact of our actions on future generations and their implications for intergenerational equity; the elaboration and codification of intergenerational rights and obligations in relation to the planet and the development of the international legal duties associated with certain activities into legal instruments; and global learning and education to raise the public consciousness of all peoples in all age groups of the need to conserve the planet and our cultural resources for future generations and to encourage public participation in relevant decision-making processes. These strategies can be implemented at the local, national, and international levels.

Representation to Future Generations

While the decisions we make today will determine the initial welfare of future generations, they are not effectively represented in the decision-making processes today. While they may be willing to pay us handsomely to prevent certain actions or to have us undertake others, they have no way of voicing this preference.[14] Representation must take place at several levels: in administrative decision-making, in judicial decision-making, and in the marketplace.

To influence administrative and judicial decisions we can appoint and publicly finance an office that has responsibility for ensuring that the interests of future generations are considered, for ensuring that laws regarding our environment and natural resources are observed, for investigating complaints, and for providing warnings of pending problems. States should be encouraged to give standing in their national courts and administrative bodies to a representative of future generations, who might function as a guardian *ad litem*. Other approaches are to designate an ombudsman for future generations or to appoint commissioners for future generations. These could operate at multiple levels: international, national, regional, and/or local. The World Commission on Environment and Development (1987, p. 332) recommended that countries consider an ombudsman at the national level.

Future generations are not effectively represented in the marketplace today; they must be. This requires that first we understand the fundamental entitlement among generations correctly. Under the theory proposed in this chapter, future generations have an equal claim with the present generation to use and benefit from the natural environment. Using this premise, the task is then to develop the appropriate mix of economic instruments to achieve the entitlement most efficiently (Norgaard, 1991). Proper natural resource accounting is an essential instrument.[15]

Assessment of Impacts on Future Generations

If we are to avoid or mitigate adverse effects on future generations, we must assess the long-term effects of our actions today on them. While under the US National Environmental Policy Act environmental impact statements must consider long-term effects, they do so, if at all, from the perspective of the present generation. In other cases, including the 1992 UN Convention on Environmental Assessment in a Transboundary Context, the consideration of long-term effects is not explicitly required. We need to start from the interests of future generations and ask what the effects of our actions will be on those interests. By starting from the perspective of future generations, we may begin to rectify the present imbalance in impact assessment, which favours the present generation. It may be appropriate to have the private sector, in particular transnational corporations, multilateral banks, and private

[13] Weiss, 1989. The others include sustainable use of renewable resources; monitoring; scientific research and technological development to enhance understanding, develop substitutes, and increase exploitation and use efficiency; and maintenance of facilities and services (Weiss, 1989, pp. 119–52).
[14] See Chapters 9 and 11 in this volume by J. Rothenberg for detailed analysis of this problem and for Rothenberg's distinction between intertemporal issues and intergenerational ones.
[15] Rothenberg also emphasises proper natural resource accounting in his backward indebtedness model (see Chapter 11).

banks, provide intergenerational impact assessments for activities which will significantly affect the well-being of future generations in relation to their natural environments.

Elaboration and Codification of Intergenerational Rights and Obligations

To encourage cooperation between countries and among communities to fulfil obligations to future generations, it is useful to elaborate and codify as many of the relevant norms of intergenerational equity as possible. Codification reduces the ambiguities about the behaviour that is expected of parties. It defines cooperative behaviour and distinguishes it from uncooperative behaviour. Some of these legal instruments will be nonbinding. Others may be binding or may become binding over time. To the extent that the norms contained in the instruments represent customary international law, all countries would be bound whether or not they were party to the relevant agreement. Some instruments would be general ones that would articulate intergenerational rights and obligations; others would be directed at the use and conservation of specific resources, such as forests, soils, fresh water and biologically diverse marine areas; still others might facilitate the scientific research and development required to develop alternative resources or to use resources more efficiently.[16]

International regimes, including regional and bilateral ones to manage or to coordinate measures for managing particular natural or cultural resources or activities affecting these resources, are also important. They increase the likelihood of cooperative behaviour when there are many participants, as in the international community. They also facilitate the development and exchange of information, make it more difficult for a party to defect since there are costs involved, and may facilitate the development of new norms.

Global Learning and Public Participation

To change the approach that we presently use to address intergenerational concerns may require a new ethos that is planetary in scope and encompasses all generations. Since the well-being of even a community's own future generations depends upon the general planetary environment in which they will live, every community must arguably be concerned about the willingness and the ability of all members of the present generation both to use and to conserve the planet for future generations.

For this to happen means that people need to develop a public consciousness about the issues and to be informed about environmentally sustainable development. The rapid and impressive development of information technologies will make the gathering and dissemination of relevant information much easier and will make such information more accessible. Nongovernmental organisations have already assumed an important role in drawing attention to environment and development issues, in mobilising communities, and in exerting pressure on decision-makers, whether locally, nationally, or internationally.

Implementing our responsibilities to future generations will be difficult. Our institutions, whether they be international, national, or local, are designed to handle relatively short-term problems of several years' duration. They are for the most part not well suited to address long-range problems, particularly those whose effects may not be felt for a generation or more. Most political systems have a short-term perspective built into them. Powerful political incentives encourage those in positions of power to focus on short-term issues so that they will have tangible results to show. Similarly, private businesses are forced by the workings of the market to take a relatively short-term view. But intergenerational equity is based on a long-term perspective. Achieving it will require adjustments in institutions, economic incentives, legal instruments, public consciousness, and political will.

[16]For a comprehensive list and cross-referencing of relevant international environmental instruments, see Weiss et al. 1992, and for a statistical analysis of multilateral environmental agreements, see Chapter 12 by P. Haas in the present volume.

Approaches to Intergenerational Equity in Climate Change: A Review and Critique[1]

PRODIPTO GHOSH[2] and JYOTSNA PURI[3]
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1. Introduction

Questions of equity in the Global Climate Change policy are grouped, for convenience, into two categories, **Intra-** and **Inter-** Generational equity. The former relate to equity in a spatial sense, that is, between different nations or global regions, and societal groups within or across them, at a point in time. The latter refer to equity across time, each generation being treated as an aggregate across the globe. Additionally, the issue of legal liability regimes for environmental harms in general, and the global environment in particular, has figured in the agenda of policy research. *This study is about intergenerational equity.*

Formulations of equity principles in the context of spatial equity in Climate Change have varied across scholars, but a pattern is evident in such variations. For example, regarding future emissions rights for Greenhouse Gases (GHGs), Industrialised Countries' (ICs) analysts have tended to *"grandfathering"* approaches, which would largely legitimise the present situation (e.g. Young, 1991). Developing countries' researchers, on the other hand, on similar questions, have furnished *"human rights"* type formulations, which may involve significant reassignments on global environmental assets (e.g. Ghosh, 1991).

Before we extend the debate to intergenerational questions, it is necessary to enquire whether the conventional neat separation of such equity issues into spatial and intertemporal aspects is meaningful. In a superficial sense, certain policy issues may indeed, fit into one or the other category. For example, the allocation of GHGs emissions rights across countries at a point in time, looks *prima facie*, to be a spatial issue. On the other hand, the path of (global) depletion of fossil fuel resources (or alternatively, actual Climate Change), appears an intertemporal question. However, two considerations would suggest that questions of equity are correctly treated as an integrated whole.

The first relates to whether the *policy issues themselves* are separable into spatial and intertemporal categories. For example, can allocations of present GHGs emissions rights *be considered* without reference to historical emissions?[4] Alternatively, is it meaningful to discuss the question of compensation for future adverse impacts in a given society, without considering the responsibility of other societies for elevated GHGs concentrations which lead to the impacts? Additionally, can the issue of bequests to future generations to compensate for depletion of exhaustible isolated be isolated from the question of spatial distribution of such bequests and its relation to spatial responsibility for the depletion?

The second is whether the *"agents"* across whom issues of equity relate[5] are divisible into spatial and temporal categories in a manner enabling differential treatment. In other words, is spatial affiliation (nationality, race, religion, gender) moot when one considers the interests of a given generation? Additionally, is temporal affiliation a distinction which *ipso facto* merits differential (lesser or greater) consideration than spatial categories (nationality, etc.)? Alternatively, do different ethical norms apply in respect of spatial and temporal categories?[6]

Our responses to both queries is in the negative. Nevertheless, in order to adhere to the format of the IPCC process, we focus on (some) intergenerational equity formulations which have appeared in the literature. We believe, however, that our analytical framework

[1] This effort has benefited from discussions with and criticism by Chranjeev Bedi. The usual disclaimers apply.

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[4] It is necessary to clarify that we do not mean that pure "grandfathering" or pure "per capita" allocations are impossible. What we are saying is that history cannot be excluded from the *discussion* of appropriate principles.

[5] By general consensus, embodied in several of the Rio Agreements, these agents are "human beings" (only).

[6] For example, is a Cost-Benefit approach (utilitarianism) appropriate across nations, but Rawls' egalitarianism across time?

applies in a more general sense, and that holistic approaches to equity questions are appropriate.

What exactly are the entities of concern in Climate Change policy making, whose distribution is the subject of equity norms? These entities relate to broad categories of elements of individual and societal well-being, and are first, conventional economic costs and benefits, for example those related to GHGs mitigation strategies, which have market nexus and therefore a price in exchange[7]. Second a set of costs and benefits which are not in themselves marketed, but nevertheless may be imputed economic value through market information[8], though such imputation frequently runs into problems of credibility with policy makers.

It is however, a third entity, which to our minds merits special consideration in equity formulations in long-term Climate Change. This entity comprises values for which imputations of price are *irrelevant*, for the reason that their loss is *inherently uncompensable*. Loss of individual human life and subsistence are clear examples. Loss of cultural identity through erosion of the specific resource base on which the culture has evolved, for example, due to the submergence of small island territories through sea-level rise, is another.[9] The question of long-term sustainability, to our minds, relates not just to the question of maintaining levels of consumption (and perhaps per-capita income growth), but also, *perhaps more importantly*, to ensure conservation and flourishing of these values. It is unnecessary to review in detail the scientific prognoses of Climate Change impacts[10] to realise that impairment of just these values are involved, no less than costs and benefits relating to the first and second entities. It would also be apparent that ethical approaches or techniques which are based on information regarding values in exchange or costs (which relate to the first and second entities), cannot easily take account of the values of the third entity. We need to locate conceptual tools which may embody all three entities' values.

2. The Ethical Premises of the Study

This section presents the ethical premises of the study, i.e., the bases in terms of some requirements of the formal theory of ethics of the evaluation of competing, allegedly ethical, norms of intergenerational equity in the global environmental context.

The Formal Theory of Ethics: A Review of Concepts

In this sub-section, we present in bare outline, some relevant aspects of the formal theory of ethics.[11] This presentation will facilitate the specification of the actual ethical premises adopted, which are presented in the next sub-section. It is our view that an explicit statement of the ethical premises is essential for defensible analyses of the various approaches to the problem of intergenerational equity, which is accomplished in the subsequent sections.

The appraisal of actions and policies raises two questions about both goals and beliefs: (i) What are the proper principles or standards to be used in appraisals? (ii) What is the rational basis for regarding any principle or standard as proper? Ethics is the philosophical discipline concerned with these two questions about goals. Two major aspects of this discipline are, **normative ethics**, *i.e., the analysis and development of criteria for evaluating moral questions*, and **meta-ethics**, *i.e., the logical analysis of the meanings of moral concepts and of the methods of validating moral judgments.* The central questions of *normative ethics* are of the form: *What criteria justify claims about the rightness, goodness, or justice of public actions?* By contrast, questions in *Meta-ethics* are of the form: *What (meta-ethical) criteria warrant the choice of (ethical) criteria employed to justify claims about the rightness, goodness, or justice of public actions?*

Two main divisions in *normative ethics* are between **deontologists**, who take as basic such concepts as *right* and *wrong*, and **teleologists**, who take as basic concepts such as *good* and *valuable*.[12]

The function of *meta-ethical theories* is to answer questions about normative ethical claims themselves: *Can we determine the truth and falsity of normative ethical claims?* Answers to such questions furnish two major approaches to meta-ethical theories: **cognitivism**, and **non-**

[7]For example, capital, fuel, labour, outputs of marketed goods and services.

[8]For example, the value of a recreational amenity may be estimated by aggregating the opportunity costs of travel to that amenity. Another example is the contribution of (non-marketed) pollution to the value of residential housing: Market prices of land may be disentangled into the contributions of different attributes, including the level of pollution, by econometric analysis.

[9]"Will India remain India without the monsoons? Will Brazil remain without her Amazon? Will Russia be recognisable without the snowdrifts of Siberia? Will Arabia be Arabia if it is no longer desert? Will England be England without wet weather?" Unfortunately, in the context of long-term Climate Change, these are not rhetorical questions.

[10]Such values may be eroded, for example, by the advance of deserts, change in cropping patterns, loss of species, deforestation, change in water resources, altered patterns of extreme weather events, and sea-level rise.

[11]*This review relies on Gewirth (1985), and Dunn (1983).*

[12]Another group, distinct from teleologists, the *axiologists*, affirm that certain actions are right because of the value or goodness that they intrinsically contain, such as happiness or pleasure, and not merely because of their consequences (e.g., meting justice).

cognitivism, each with internal subdivisions. Meta-ethical theories differ in terms of their assumptions about the epistomological status of normative theories. *Cognitivists* affirm that normative ethical theories are capable of being true or false and of constituting a kind of knowledge; while *non-cognitivists* deny that they are knowledge, and instead see them as expressing attitudes or furnishing commands. Meta-ethical theories are closely but imperfectly associated with normative ethical theories. For example, the growth of *logical positivism* in the social sciences has contributed to non-cognitivist meta-ethical doctrines which, in turn, have devalued normative ethical discourse. *This in turn, has resulted in a trained incapacity to recognise that putative empirical theories (welfare economics) and analytical routines (Cost-Benefit Analysis) are based on controversial ethical premises.*[13]

Cognitivists are of two species, the **intuitionists (or non-naturalists)**, and **naturalists**. The former consider moral terms and judgments as unique to ethics, while the latter affirm that they are akin to the kind of knowledge found in the natural sciences. According to *intuitionists*, the basic moral term signifies a non-natural and indefinable quality. They deny that moral terms are reducible to the kind of knowledge produced in the physical and social sciences. According to Moore (1903, 1912), the basic moral term is "good", while according to Prichard (1949) and Ross (1930, 1939), it is "ought", representing axiological and deontological views respectively. According to all three, the basic term denotes a certain objective property that is grasped by immediate intuition. On the other hand, *naturalists* directly identify moral qualities with empirical qualities. There is no separate existential category of moral quality, nor is a separate kind of cognition necessary to ascertain them, i.e., moral concepts are verifiable by the same means as are other scientific statements, and moral knowledge is therefore, part of natural science.

In contrast with cognitivists, *non-cognitivists* deny that moral terms have any descriptive meaning. *They do not accept that moral judgments either state facts about the world, or that reason can justify any moral principle, or more generally, that there can be any definitive justification of a moral judgment.* In particular, non-cognitivists hold that moral terms have various types of non-descriptive meaning: they express feelings or emotions; they express attitudes; they exert influence; they issue commands; they guide choices; they commend or condemn. An influential non-cognitive position has been that disputes over moral principles cannot be decided by cognitive consideration alone. If two disputants agree on moral principles, then cognitive considerations alone, in particular appeal to empirical facts, will enable them to resolve the dispute. However, if they disagree on moral principles, then cognitive considerations are of no use. Opponents have pointed to the parallel fact that when persons disagree on scientific principles, then too, cognitive considerations are of no help. The difficulty with cognitive undecideability is not unique to ethical questions. Another argument on this point relates to the logical structure of moral reasoning. Non-cognitivists argue that an *"ought"* cannot be derived from an *"is"*, i.e., purely factual or descriptive premises cannot logically lead to any moral judgment, because of the *assertion* that "nothing can appear in the conclusion of a valid deductive argument which is not, from their very meaning, implicit in the conjunction of the premises". Because cognitivist arguments purport to infer "ought" from premises in which it or some word related to it by definition does not appear, their inferences are invalid. One objection to this argument is based on the "logic of material implication", i.e., a false statement materially implies any statement (true or false), so that an ought statement is logically derivable from any false statement. Further objections to the principle of no "ought" from "is" also exist.

The question of what actions are morally right or wrong is central to *normative ethics*. The resulting ethical judgments have direct implications for human actions, social institutions, and ways of life.

Deontological theories do not and *teleotological* theories do, appeal to value considerations in answering the central question of normative ethics. Further differences between these two approaches are: (1) Deontological theories advocate doing certain things because they conform to some formal principle or are inherently right (e.g. employee participation), while teleological theories appeal to their (value) consequences (e.g. maximisation of net income benefits); (2) Deontological theories set forth certain absolute obligations (e.g. freedom is a generic right that cannot be justified in any other terms), while teleological theories furnish only conditional obligations (e.g. freedom might be

[13] *Philosophers have also been concerned with analysing the concept of morality itself*, i.e., as opposed to *non-moral* (rather than immoral or amoral), for example, aesthetic, prudential or legal. Two main approaches are that for any moral judgment, certain **formal** conditions must be met; alternatively, that it must fulfil a **material condition**. *Formal* conditions include, that the rules or judgments must be **prescriptive or universalisable**, or have **overriding importance** or authority. The *material* condition is that the judgment or rules must relate to the welfare of the society, or at least to the interests of persons other than the judge. Formal conditions are clearly deontological in spirit, while material conditions are closer to teleological or axiological approaches. These distinctions are, of course, ancient.

abridged in the interests of national security); (3) Deontological theories propose formal or relational criteria (e.g. social equity or administrative impartiality), while teleological theories furnish material criteria (e.g. pleasure and happiness); (4) *Deontological theories furnish distributive criteria*, concerning how goods and bads should be divided among persons, while *teleological theories set forth aggregative criteria* such as maximisation of goods/minimisation of evils; and (5) Deontological theories furnish plural as well as unitary criteria (e.g. justice, freedom, well-being), while teleological theories furnish only a unitary criterion (e.g. welfare maximisation).

Deontological theories may be **material** or **formal**. The former holds that the criteria of rightness (obligatoriness) of actions consists in some feature of either of the actions themselves or of their background. The latter holds that it consists in some logically necessary relation between the judgments or rules, in accordance with which the actions are performed. *Material* deontological theories in turn, may be **pluralistic**, i.e., the features of the actions or backgrounds that make them obligatory are of different kinds,[14] or **monistic**, i.e., they are ultimately of one kind.[15] Critics of *pluralism* point out that if no general reason can be given why certain acts are obligatory, there is no way of dealing with ethical disagreements. The **principle of consent** is a prime example of a monistic material deontological principle, according to which an action is obligatory if and only if the person who has accepted the obligation has voluntarily consented to it, directly or tacitly. Through the theory of the *social contract*, political obligation has been held to rest on such consent.

The general point of *formal* deontological theories is that, if the performing of certain kinds of action logically commits one to self-contradiction, the actions are not rationally justifiable. Performing these actions are then not one's duty, but it is also one's duty to refrain from them, and perhaps rationally also to perform some other, opposed action. **The principle of universalisability** is one key logically necessary relation between ethical principles. In its most general form, it says: If some predicate P belongs to some subject S because S has some quality Q (where the "because" is of sufficient reason), then logically P must belong to all other subjects SI, S2,... ,Sn, that have Q. The principle applies to morality in the following sense: What is right or wrong for one person must be right or wrong for any similar person in similar circumstances. Three questions which arise in its application to ethical evaluation are as follows: (1) The question of commitment to a general rule: The objection is that every situation is in some sense unique, so that a person making an ethical judgment in his own situation is not required to "legislate for everyone else". The reply is that if a person gives reasons for his actions, and these are claimed as sufficient, he is logically required to accept the corresponding general rules that apply to all other persons who fit the description contained in the given reason. (2) The question of relevant similarities: The principle refers to similar person under similar circumstances, but does not reveal what attributes or circumstances are to count as relevant. The answer, is of course, that the person claiming that his actions are ethically right must also specify the sufficient attributes or circumstances making it so, and these in general form, cannot in logic be denied to all other persons fitting the general description. (3) The question of the standing of the principle of universalisability as a moral principle, i.e., is it a necessary or sufficient condition of moral rightness, or neither. Judging by the burden of evidence of policy making and legislation throughout the globe, it would appear that empirically, the proposition that it is at least a necessary condition in matters of distributive justice, would seem to be defensible. **Kant's categorical imperative** *("act only on the maxim through which you can at the same time will that it should become a universal law")* is the best known example of the principle of universalisability being regarded as a sufficient basis of moral rightness in a monistic formal deontological theory.

Teleological theories are distinguished from one another by what they say is (1) the nature of the goods or values to be maximised (e.g. national prestige, GDP), and (2) the locus of the goods, i.e., the persons or groups whose good is to be considered. To some extent, the answer to (1) helps answer (2), for it may be held that only certain kinds of persons are capable of attaining certain kinds of goods. For example, only Plato's philosopher kings are capable of having the good of power. However, when the good is universally attainable, such as pleasure or happiness, limitations of its locus are less plausible.

The two extremes of teleological theories relating to the *locus of goods* are **Egoism,** and **Welfarism,**[16] which hold respectively, that it is the good of the agent himself (or of members of defined categories, e.g. based on religion, race,

[14]For example, actions such as keeping promises, repaying benefits, etc., are inherently and self-evidently obligatory, and no further reason can be given for their being so.

[15]For example, "will of God", conformity to nature or human nature, consent or contract, etc.

[16]Actually, the term employed in ethical theory is **Utilitarianism.** In this paper, we employ the alternative *welfarism*, to distinguish it from *utilitarianism* in the special sense employed by neo-classical elfare economists, i.e., aggregation of "willingness to pay" for net benefits over all members of society, or equivalently, "increase in (economic) efficiency". The economists' "utilitarianism" is clearly a species of the generic "utilitarianism" of welfare theory. Further note that what economists mean by "welfare" is a notion of societal good based on individual preferences of all members of the society.

nationality), or the good of mankind, which determines whether actions are morally right. Egoist theories are of two main kinds. The **individual egoist** holds that the duty of all persons is to maximise his own respective good. Plausible arguments in its favour are difficult to furnish. If it is based on certain characteristics of the individual whose good is to be maximised, then it must equally permit the good of any other persons having the same characteristics to be maximised.[17] If it is based on characteristics which are really unique to an individual, it is difficult to see how these characteristics should be relevant to the allocation of goods. If the individual egoist appeals to no characteristics of the individual, the doctrine has no justification at all. These considerations apply *mutatis mutandis* to at least some of the **restricted locus** theories based on religion, race, nationality, etc. **General egoism**, on the other hand, draws support from *psychological egoism*, the doctrine that each person in fact seeks to maximise his own respective good.[18] The implicit premise is that each person *ought* to pursue what he actually *does* pursue. This counter-intuitive result obtains by illicitly moving from the premise that the purpose of any action is the person's own, to the conclusion that the purpose is the person's own good.

Welfarist theories are universalist, i.e., they hold that what a person ought to do is to promote the maximum good *of all*, i.e., the general good. The term "general good" is however ambiguous, in the sense that it may relate either to (1) the greatest good no matter to whom it accrues ("good aggregative" welfarism), or (2) on distributing the good over as many persons as possible ("locus aggregative" welfarism). The first would be concerned only with the total amount of good, the second also, or mainly, with how many get it. Classical Utilitarians, such as Jeremy Bentham and John Stuart Mill seem to have been more inclined to locus aggregative welfarism, because the formula they upheld was "the greatest good of the greatest number". The second view is clearly consistent with the formal deontological principle of universalisability.

The most serious problem with welfarism (Utilitarianism) is that neither approach specifically provides for distributive justice. The utilitarian dictum: *"Everybody to count for one, nobody for more than one"*, provides not for equal (or even equitable) distribution, but only for *impartial consideration* of persons as possible loci for distribution. Of course, several neo-classical welfare economists have held, on the grounds of diminishing marginal utility that the more equal is the distribution of wealth in any society, the greater is the societal welfare. *This conclusion rests not on consideration of equal distribution as a valued good in its own right, but only as a means to maximising welfare (sum of cardinal utilities).*

The Ethical Premises Specified

In later sections, we evaluate various approaches which have appeared in the literature, on the question of intergenerational equity in global environmental issues. The ethical premises of such evaluation, deriving from concepts of formal ethical theory (outlined above), are detailed as follows. Reasons for their adoption have been discussed above, and are not repeated: In respect of *meta-ethical* considerations, we reject the non-cognitivist argument, for the *contingent reason* that thereby no evaluation of different approaches to the question of intergenerational equity would be possible, since non-cognitivism demarcates ethical issues from other intellectual quests as not decideable in a cognitive sense. In other words, *we assert at the outset that rational evaluation of ethical issues, including the focus of this study, is indeed possible.* It is unnecessary for our purposes to take positions on further sub-divisions of cognitivism.

In respect of *normative ethics*, we consider that deontological and teleological approaches are *not incompatible*. In other words, particular approaches to the question of intergenerational equity may embody either or both approaches. *However, we do assert that all such approaches must adhere to the formal deontological, "principle of universalisability"*, in order to remain in reckoning for policy making.

With regard to teleological ethical schools, *we reject ethical-egoist approaches*. Among these, *individual-based* ethical-egoist theories are rejected on account of the implausibility of the characteristics of a unique given individual being relevant to the distribution of benefits, while *restricted locus* theories are rejected for the same reason, and also as violative of the principle of universalisability. *General egoism* is rejected for, as noted above, it moves incorrectly from the premise that the purpose of any action is the person's good, to the conclusion that the ethical purpose is the person's own good.

A particular symmetry between intra (or spatial) and inter-generational equity may be noted. The principle of universalisability would disallow differential treatment to persons based on race, religion, nationality, etc., in either case. In the latter, the further question arises whether

[17] This follows from application on the principle of universalisability as a necessary condition for distributive justice.

[18] This corresponds to the utility maximisation paradigm in neoclassical economics.

distinctions may be made between persons on the basis of the generation they are born into. If particular approaches to intergenerational equity involve differential treatment across generations, the fact of differing generation itself must be demonstrated to constitute relevant dissimilar circumstances. The burden of such demonstration would lie with the authors of the particular approach.

3. The Cost-Benefit Approach[19]

The reigning liturgy in project appraisal is Cost-Benefit Analysis (CBA). While this family of techniques was originally developed to rank projects of modest time horizons, and which were individually small in relation to national economies, there have been attempts to apply CBA to projects involving long-term environmental impacts. The following discussion and critique pertains to the question of intergenerational considerations in these attempts.

The salient aspects of the approach are as follows: CBA techniques rank alternative projects (policies/programmes) on the basis of four factors: the stream of benefits that they generate, the stream of costs that they impose, the time periods over which these benefits and costs occur, and the social discount rate applied to them. Discounting benefits and costs to present value as they occur over time enables the streams to be collapsed into a common metric, the Net Present Value (NPV), to enable the ranking of policy alternatives.

The issue of *intergenerational equity in CBA* relates to *choice of a social discount rate*. This is usually taken to be positive, i.e., $1 worth of cost/benefit incurred in the future is worth less than $1 worth of cost/benefit today. This is justified on two considerations. One, the marginal *productivity of capital*, which means that a small amount of real resources not consumed today can, if put to productive use, yield, more than their own value in future. Two, the (positive) *personal rate of time preference*, which means that individuals are willing to give up more than $1 worth of consumption in the future to obtain $1 worth of consumption today. These are reflected in the *market rates of interest*, and the *market rates of return*, respectively. In a perfectly competitive capital market with no taxation and no uncertainty, these would be equal. The NPV thus computed is identical to the "gain in economic efficiency" from the project.

The social discount rate may, however, *be chosen to differ* from the market interest rate. Reasons for such choice may include: (1) Individuals are viewed as "myopic", i.e., the present generation may discount the future too highly and the interests of future generations not given sufficient weight. (2) It is believed that for *public projects* a different discount rate *should* apply. This may be on account of, for example, that individuals as voters viewed tradeoffs between the present and future differently than as private consumers. Alternatively, for environmental concerns, the benefits may be viewed as generically different from those involved in private consumption decisions, or because citizens expect the state to assume particular responsibility for the interests of future generations.

In respect of *non-environmental considerations*, approaches to choice of social discount rate arise from choice of numeraire. The first, *"aggregate consumption at domestic market prices"*,[20] involves the use of a *consumption rate of interest* as social discount rate, and requires shadow pricing of costs and benefits to take account, *inter-alia*, of the sources of investment funds and the uses to which the benefits are put (consumption or investment, public or private). The second, *"uncommitted social income measured at border prices"*,[21] implies the use of an *accounting rate of interest*. This differs from the consumption rate of interest, and while shadow pricing of costs and benefits are again involved, it is computationally the simpler procedure, since the numeraire is public income, which may be used for public investment.

The **consumption rate of interest** is derived as:

Consumption rate of interest = (rate of pure personal time preference) + (elasticity of marginal utility of consumption) x (expected growth rate of per-capita consumption).

The **accounting rate of interest is**: *"the fully adjusted social opportunity cost of capital, taking account of the differential valuation of savings and consumption"*. It is the proportional decline over time of the value of government income, measured at border prices. While no exact expression for it in terms of measurable variables has been obtained, a widely used approximation is furnished by Squire and Van der Tak (1975). If government income and private consumption have the same value, and there are no distortions in consumer prices, the accounting rate of interest equals the marginal product of public sector capital.

Where *environmental issues* are involved (and important), these bases of choice of social discount rate have been questioned. Two arguments are: (1) conventional social discount rates in general tend to encourage early depletion

[19]The presentation of the CBA approach in this section relies largely on Markandya and Pearce (1988).

[20]The UNIDO approach.

[21]The Little-Mirrlees approach.

of natural resources; and (2) discriminate against future generations.

There is in fact no unique relationship between the social discount rate adopted and environmental degradation. This is because while high social discount rates may shift the cost burdens to later generations, if social discount rates determine levels of investment, lower social discount rates will reduce overall investment and hence economic growth. Further, if natural resources are necessary for investment, a result from the theoretical literature based on conservation of mass is that the demand for natural resources is less with high social discount rates. These considerations leave one with having to deal directly with the claim that high social discount rates are detrimental to future generations. The various specific arguments are considered in turn:

Pure Time Preference. The various arguments against permitting (individual) pure time preference to influence choice of social discount rates are: (1) Time discounting, because of impatience, is irrational. (2) Individual preferences carry no necessary implications for public policy, at least in the intergenerational context. This amounts to a categorical repudiation of utilitarian (or more generally, welfarist) normative ethical schools. (3) The underlying value preference is improperly expressed, i.e., it is the satisfaction of wants *as they arise* that matters, not today's preferences over tomorrow's satisfaction.

Risk and Uncertainty. Conventional economic wisdom holds that a cost or benefit is valued less the more uncertain is its occurrence. Since uncertainty is usually expected to increase with time, this dependence is formally expressible as a discount rate for risk and uncertainty. Some arguments for using risk and uncertainty to justify positive social discount rates, together with several objections are: (1) Uncertainty arising from an individual not being sure that he will be around to receive a future benefit (the "risk of death" argument). This argument ignores the fact that society is immortal, and distant benefits will occur to society anyway (which is what matters in the utilitarian/welfarist ethical tradition). (2) Uncertainty about preferences, even if the existence of the individual is certain. While uncertainty regarding preferences for certain goods is plausible, this is hardly the case where future availability of food, water, shelter are at stake. (3) Uncertainty about the presence or magnitude about benefits and costs may be unrelated to time.[22]

Diminishing Marginal Utility of Consumption. The consumption rate of interest, which in CBA routines with aggregate consumption at market prices as numeraire is the social discount rate, involve the marginal utility of consumption. This parameter is, however, not directly observable, and many economists dispute whether it can at all be measured. Further objections involve the idea that if the individuals in different time periods are different, which would certainly be the case in intergenerational policy situations, interpersonal utility comparisons are involved, which involves strong assumptions. Another major problem is that empirically, the prevalence of poverty results in high rates of time preference. This is problematic because high rates of time preference may be a cause of environmental degradation, as poor individuals satisfy immediate needs for food, fuel, water, to the detriment of long-term sustainability. However, environmental degradation itself may have caused the poverty in the first place, which leads to high rates of time preference. The apparently high rates of time preference are clearly, not independent of environmental conditions.

Opportunity Cost of Capital. Several economists have taken the position that the social discount rate should be the rate of return on the marginal project displaced by the investment in question. Two specific criticisms of this approach are: (1) The *discount factor* increases exponentially with time, reflecting the assumption that all (net) benefits are reinvestible. However, some benefits may not be reinvestible, even in principle.[23] (2) The second argument is symmetrical to the first, but with respect to intergenerational *compensation*. If some future harms are uncompensable, even in principle, it makes no sense to discount their (future) cost on the underlying assumption that a present investment (equaling the present discounted value of the future valuation of the harm) would yield the compensation. However, CBA as conventionally applied does not require actual compensation.[24]

It has been argued very generally, that *any market rates of discount* are inappropriate in policy situations where the interests and rights of future generations are at stake. The arguments may be summarised as follows: (1) With higher social discount rates, which would be the case if market discount rates were to be employed, projects with long-term costs and short-term benefits are likely to meet investment criteria, and conversely for projects with long-term

[22]For example, future GCM projections for climate change may significantly eliminate uncertainty about future impacts.

[23]This would be the case for example, when the benefit involves conservation of wilderness.

[24]This point is discussed more fully in our critique (next page).

benefits but short-term costs. (2) The higher the social discount rate the lower the overall level of investment, and hence the lower the capital stock bequeathed to future generations.

Conversely, it is argued that existing preferences revealed in market discount (interest) rates *do* take account of future generations interests, by way of the welfare of future generations counting as one of the factors determining present utility levels. Of course it cannot then also be claimed that market determined discount rates reflect any recognised *rights* of future generations.

The point, however, is that individuals make decisions in two contexts: *private* in which their own[25] interests are involved, reflected in market discount rates, and *public*, in which responsibility for others in society, including future generations,[26] is involved, and which should be reflected in social discount rates.[27] The *"assurance"* argument is similar, that is, people may behave differently if they can be assured that their own action will be matched by similar actions by others. Yet another argument to justify the inequality of market discount rates and social discount rates is the *"isolation paradox"* which notes that individuals will *not* make (intergenerational) transfers even if others do so. In summary, therefore, the argument is that since any positive social discount rate will discriminate against future generations, the choice of social discount rate is not to be left to the market or some aggregation of current generations' preferences, but should be determined through a collective social contract.

Critique of the Application of CBA to Intergenerational Environmental Issues

CBA techniques involve one of two alternative assumptions. The first, is that *increases in economic efficiency* are the proper objective of public policy. *This is exactly equivalent to the adoption of utilitarianism (aggregation of willingness to pay for net benefits individually received over all members of society) as the (normative) ethical basis of policy making.*

The alternative, is that *policy makers have at their disposal a suite of policy instruments (e.g., direct taxes, welfare payments), which may be employed to costlessly reassign benefits and costs across different members of society in line with any distributive norm that the state may care to adopt. Given this assumption, increases in economic efficiency are unambiguously desirable.*

The second alternative is of course meaningful in the intergenerational context only if a normative ethical basis (which may even be utilitarianism itself) is agreed upon by policy makers for intergenerational transfers. Moreover, policy instruments must actually exist, or be feasible to adopt, to effect such transfers. In either case, the possibility of maximising economic efficiency must be demonstrated. We will revert to these considerations later.

Our critique of these CBA approaches commences with a discussion of the *possibility of realisation of the utilitarian ethic,* or maximisation of gains in economic efficiency, in intergenerational policy issues, in particular those with long-term environmental impacts. We recall that welfarist ethical theories (including utilitarianism) *are universalist,* in line with the dictum: *"Everybody to count for one, nobody for more than one"*, meaning impartial consideration of all persons as possible loci for distribution. *If equity across the generations is intended, every future generation must count equally with the present in the welfare aggregative process involved in utilitarianism.* In any event, the ethical premises we have specified would rule out any interpretations of utilitarianism which is inconsistent with the principle of universalisability. A major problem arises from the fact that costs and benefits of projects or policies are in respect of *dated goods and bads.* This means that the present generation may experience direct satisfaction (express a willingness to pay), *only in respect of the goods and bads which fall into its temporal lot.*[28] In respect of goods and bads which are contemporary with other generations, the present generation can experience only vicarious satisfaction via its valuation of the satisfaction received by the respective generations. If utilitarianism is to be realised by consideration of the preferences of the present generation alone, two conditions are clearly necessary for the welfare of all generations to count equally in the process of aggregation. First, *there must be no discounting of the welfare of future generations.* Second, *one must have perfect knowledge of the preferences of future generations.* The first condition implies that *any positive social discount rate (in respect of actual welfare, not necessarily consumption) is disallowed under the utilitarian ethic.* The second condition is clearly too strong to be credible.[29]

Our next critique relates to the neo-classical economists' prescription of the consumption rate of interest as the social discount rate. The

[25]Presumably including their own offspring.

[26]That is, apart from one's own offspring.

[27]Termed the *"dual role"* rationale for sdrs being below market discount rates (Sen, 1985).

[28]This is of course trivially true for any generation, but this fact does not alter the argument.

[29]A special case of this assumption is unchanged preferences across generations. Any person who has teenage offspring will vouch for its implausibility.

assumptions in its derivation are:[30] (1) The welfare function of *an individual* is concave in the level of consumption; and (2) for a given level of consumption, declines exponentially over time.[31] The consumption rate of interest is defined as the rate of fall of the marginal welfare of consumption.

Several problems arise with this formulation in the intergenerational, environmental context. First, since the welfare function relates to an *individual* (we may stretch "individual" to include all members of a given generation to keep the argument simple), the fact that consumption is dated means that the time domain of the welfare function cannot extend beyond that individual's lifetime. This means that *the "pure time preference" parameter relates to just that generation, and not future generations.* Second, in the context of environmental impacts, non-convexities (or discontinuities) in the welfare function are likely. This may mean, for example, that certain types of consumption, for example subsistence calories gleaned from natural resources (including climate), may have a lower bound below which welfare falls sharply (or is undefined) at any time.[32] The "marginal welfare of consumption" may be undefined at such non-convexities or discontinuities. Together the implication of these two problems is that *the notion of the consumption rate of interest ceases to have meaning in the intergenerational, environmental context.*

The use of positive social discount rates in the intergenerational, environmental context, may thus be violative of utilitarian ethics itself. They can only be justified on the basis of a restricted locus interpretation of utilitarianism, that the preferences of the current generation alone (expressed for example, in the "consumption rate of interest") count. However, this violates the key formal deontological principle of universalisability, and is thus unacceptable.

What of utilitarianism itself, as an ethical doctrine for global environmental concerns? A standard critique of the doctrine goes as follows: First, the concept of utility itself suffers from serious flaws, and is difficult to accept in an intuitive sense, as the only source of value in judging "well-being". Contingent circumstances distort the extent of deprivation in the scale of desire fulfilment. For example, the malnourished or the homeless may score high on happiness if they have learned to have realistic desires. However, any high score on this account does not reflect his actual well-being.[33] Second, right and wrong in conduct are to be calculated solely by reference to outcomes, in other words, that the end justifies the means. Utilitarianism requires people to do *whatever* act will, in a given situation, produce the best outcome overall, i.e., yielding the highest sum total of utilities (or willingness to pay).[34] Third, utilitarianism highlights the inadequacy of the evaluative criteria used, i.e., gains in economic efficiency. This is because it is concerned exclusively with the space of aggregate utilities, and is indifferent to distributive concerns. Finally, the aggregation of utilities requires the assumption of cardinal, interpersonally comparable utility, which is violative of the Arrow Impossibility theorem. This is a serious flaw in its theoretical foundations. Utilitarianism, accordingly, suffers from neglect of both substantive and procedural justice, is intuitively unappealing, and theoretically weak.

The next subsection discusses and critiques an alternative to amendment of the social discount rate, within the CBA evaluative tradition, by imposing a "sustainability criterion".

The Sustainability Constraint[35]

The concept of sustainability is frequently stated in terms of a constraint on the range of permissible intergenerational outcomes, the underlying idea being that ethical considerations dictate that the depletion of natural resources by the present generation do not jeopardise the ability of future generations to enjoy a favourable standard of living. The classic statement of this principle is, of course, the WCED's definition of sustainable development: *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. This, and similar definitions are based on the ethical norm that present and future generations are ethically equivalent, and hence it is imperative that members of future generations have equal or better opportunities than the present for a decent life.

The counterfactual to this argument (Schwartz, 1978) is that even minor policy

[30]See Markandya and Pearce (1988).

[31]There are just two arguments to the individual welfare function: the level of consumption, and time.

[32]The individual dies!

[33]A major distortion in applications to CBA is that "willingness to pay" may actually reflect "ability to pay". Accordingly, estimates of costs of climate change damage for developing countries may be much lower than for industrialised countries, even though the former may experience by far the more drastic impacts on greater populations.

[34]If the only way to prevent murders is to commit one yourself, utilitarianism would require just that. Another example is that if a given state of society which results from the actions of Robin Hood has higher utility in the aggregate than another which results from taxes and subsidies determined by lawful processes, Robin Hood's is the superior outcome under utilitarianism.

[35]This presentation of sustainability constraints borrows from Howarth and Monahan (1993).

changes may significantly alter the composition of future generations in the sense of which precise individuals will be born. This is because any particular individual's chances of being born are highly dependent on extremely contingent circumstances. Accordingly the present has, at most, extremely weak obligations to bequeath adequate resources to the future.

A simple reply to this line of argument is that the principle of universalisability does not require the identity of all agents to be determinate, only that agents should be believed to exist.

Two major approaches to sustainability are: First, the neoclassical economists interpretation that sustainability is a technical requirement that the utility or welfare of future generations should be no lower than that of their predecessors. Second, that what policy makers are choosing is not a determinate path of future welfare, but a probability distribution of potential outcomes, and the question relates to how much sacrifice is the present generation required to make to protect future generations from the risk of particularly adverse outcomes.

The neoclassical approach runs into major difficulties regarding how welfare may be defined for the purpose. A utility or "willingness to pay" approach encounters all the problems of utilitarianism. In particular, the neoclassical economists' approach finds it difficult to accommodate the third entity elements of individual and societal well-being (see Section 1). This issue requires alternative concepts which may incorporate the three entities. An approach is furnished in Section 5.

A second difficulty is exactly what level of welfare is to be preserved indefinitely. This issue is deeply intertwined with questions of spatial equity, in addition to concepts of welfare. For example, if present levels of well-being are to be continued indefinitely, does this mean that developing countries must limit their aspirations? Suppose again, that present living levels in ICs are technically infeasible to maintain, either if adopted worldwide, or just in the ICs themselves.[36] How exactly are the levels of living in different regions to be adjusted? We do not attempt to furnish answers to these issues.

The question of present sacrifices in the interests of sustainability given future uncertainty may justify some measure of partiality for the present generation. This may be reinforced in the case of DCs by the imperatives of present development. Some answers are furnished in Malnes' "bottom-up" approach, which is presented and critiqued below.

4. The Raino Malnes Approach

Malnes (1990) furnishes a set of ethical principles for intergenerational equity in the context of environmental policy choices, derived from explicitly stated premises. The approach is summarised and critiqued below:

Malnes commences with two propositions:

(i) *Each person is free to pursue his interests as long as his actions do not impinge intolerably on others ("the right of action").*

(ii) *Every government has an obligation to gear social institutions to the interests of its citizens ("the goal of development").*

Proposition (i) is logically prior to (ii). The right of action is thus qualified by the **harm principle,** which proscribes infringement of the vital interests of other persons. Interests refer to personal preferences ("desires") (e.g., fashion clothing), as well as those whose fulfilment involves well-being (e.g., nourishment). A subset of the latter are termed "basic needs" (or "subsistence"), which may include education, for example, apart from food, shelter, etc., that is they may include things which are not strictly necessary for physical survival. A fundamental normative premise is that *"needs trump desires"* and this is embodied in the initial formulation of the harm principle: *"One should not do things that jeopardise the subsistence of innocent persons for the sake of fulfulling mere desires".*

Malnes next answers the question, *"does the harm principle apply across time"*, i.e., (1) whether the basic needs of future generations count in a moral sense, and (2) how much do future needs count? The first ancillary question is answered in the affirmative, on the ground that the identities of victims (of actions which abridge basic needs) is irrelevant, only the fact that there actually be victims is necessary. The second ancillary question relates to whether future basic needs should be discounted. Three *alternative* possible answers are: (1) **Extreme temporal partiality,** that contemporaries always take precedence whenever interests conflict. This is clearly ruled out by the harm principle. (2) **Weak temporal partiality,** that contemporaries take precedence when interests of equal urgency conflict, but needs always trump desires. *Without invoking a plea of uncertainty regarding the future (about which more later), weak partiality too infringes the harm principle.* (3) **Temporal impartiality,** that there is no question of favouring the present generation simply because of its location in time, when interests of equal urgency across generations compete for public attention.

Where basic needs are at stake in both the present and any future generation ("symmetric

[36]As for example is suggested by the "Limits to Growth" study.

conflict"), two situations may arise. One, in which (roughly) equal numbers of persons in each generation are involved *("equal number conflict")*, and two, where unequal numbers are involved *("unequal number conflict")*. Malnes introduced the notion of **future uncertainty** (both malign and benign) to argue that the *principle of minimising maximin*,[37] that if contemporary needs go unmet then adversity is virtually certain to occur, and conversely, that current sacrifices for posterity may prove dispensable, allows of **permissible partiality,** *that contemporaries take precedence when interests of equal urgency conflict, and the conflict relates to equal numbers, or a greater number of present persons.*

Regarding skewed unequal number conflict, with fewer present persons pitted against a greater number of future individuals, two views cited by Malnes are: (1) *Taurek's:* that one death is as evil as five because the only loss that matters, is the loss to the persons, who die, and therefore the losses are not additive, and (2) *Sanders':* people are objects, even if rather special objects, and hence numbers do matter, a view in line with conventional morality. Malnes opts for the Sandersian view, but concedes (asserts) that a *"war of intuitions"* is involved. On the position, a small number of contemporary lives should not be allowed to stand in the way of measures which appear necessary for the survival of millions in the future. There seem however, to be few practical implications of this position.

Malnes next attempts to locate riders to the "needs trump desires" principle. One situation is where possible outcomes can be assigned probabilities, in which case a decision rule of maximising expected value[38], which would permit one to risk an extremely small probability of great loss for a high likelihood of modest gain (e.g., crossing the street in traffic). However, such tradeoff is impermissible when any gain is to oneself, but the possibility of disaster relates to others, the norm involved being the harm principle. Another situation is, where the harm is compensable, is it permissible to inflict risk on others? According to Malnes, objections to this course are: (1) there may be a time-lag before harm can be compensated, and (2) the exposure to risk may itself be a torment which assurances of compensation may not fully redeem. Since these do not apply in the intergenerational case, the harm principle may be abridged when the harms are compensable, and compensation is actually provided. An interesting situation is the possibility of claim to *compensation by the agents causing (potential) harm to desist from the action.* If a person is morally bound to inflict risk on others by actions which are morally neutral, and which will be costly for him to renounce, then he may be owed compensation for abstention. An example is that epileptics may be compensated for desisting from driving.

Malnes' thesis is clearly compelling in terms of logical consistency and intuitive appeal. At the outset of our critique, we note that by attempting to formally derive normative principles for intergenerational equity from clearly specified primitive notions, Malnes *effectively jettisons the notion of ethical judgments as noncognitivist.* The thesis thus meets our first ethical premise.

Malnes' first proposition (the "right of action") as well as its qualification, the harm principle, also adhere to the formal deontological principle of universalisability, our second ethical premise. The "right of action" refers to "each person", and thus admits of no spatial, temporal, or other restriction on who may exercise the right. The "harm principle", which is the key structural element of Malnes' doctrine, exempts none from abjuring acts harmful to (innocent) others' subsistence. It may also be held to be a **material deontological principle, i.e., self-evidently obligatory.**

The second proposition, the goal of development, is subordinate to the first. Standing alone, it is parochial, and therefore of restricted locus, since governments are enjoined to address policies to the interests *of citizens.* However, the priority accorded to the "right of action" means that Malnes' remains in adherence to our specified ethical premises.

Malnes' furnishes a justification for weak intertemporal partiality in the case of equal number (or greater number in the present generation) conflict over interests of equal urgency. The appeal is to a rule of prudence ("principle of minimising maximin") in the face of uncertainty. Can such a rule of prudence be justified in ethical terms? The rule of prudence adopted by Malnes would seem to pass the test of the harm principle, because it seeks to minimise the probability of outcomes carrying risk to others (future generations), and anyway, minimising the harm. We may note that the celebrated **Rawls' theory of justice** (Rawls, 1971, discussed below) indeed also relies on a similar rule of prudence ("the maximin criterion") in deriving its deontological ethical principles. Of course the uncertainty referred to by Rawls is contrived, for the specific purpose of deriving ethical norms from an initial "veil of ignorance", placing all agents on equal standing with respect to their future societal positions and endowments. Malnes, on the other hand, refers to uncertainty in the real world.

[37]Minimising the probability that the maximin outcome will occur.

[38]As opposed to maximin.

Malnes' one point of departure from the specified ethical premises is in upholding the (conventional morality) stance of Saunders, that two lives are worth more than one, over Taurek's view, that one death is as great a loss as five, *solely on appeal to the intuition.* The assertion that both Taurek and Saunders furnish only intuitive appeals may not be correct. Taurek may be justified on a material deontological *principle,* that saving human lives (or subsistence) is inherently self-obligatory. Saunders' position, on the other hand, (at least in respect of a welfarist notion of "subsistence"), may be justified in terms of a teleological aggregation of a thing of value (subsistence of individuals). Our ethical premises do not allow one to give priority to one over the other; however, at least it permits Malnes' choice to rescue from appeal to intuition alone, or non-cognitivism.

Malnes' one categorical abridgement of the harm principle is in respect of compensation, when victims of harmful actions are yet to be born. Two restrictions which distinguish Malnes in this respect from the Potential Pareto Improvement criterion of CBA is, first, that the *harms must be compensable.* Second, that *harms must actually be compensated.* In respect of compensable harms, Malnes accepts one neoclassical sustainability doctrine (due to Solow), that the depletion of non-renewable resources may be compensated by bequests to future generations of capital stock defined broadly, for example, inclusive of technological knowledge and human skills. This position is similar to that of *Modern Libertarianism* (Nozick, 1976), an uncompromisingly deontological normative ethic, which amends the Lockean doctrine that one may exploit nature to the extent that *"enough and as good"* is left for others, by the proviso, that what is left for others need not be the same good, but only equal in value. However, where the harms are uncompensable, Malnes would presumably adhere to the principle of "needs trump desires".

Two implications for global policy making are furnished by Malnes. First, *that policies which compromise future subsistence and are unnecessary for present needs should be terminated.* In ICs, this may call for radical reform. However, in DCs there is sharp (nearly equal number) conflict between present and future subsistence, and they cannot, in terms of the thesis (specifically, the "permissible partiality" principle) be charged with abridgement of present development for posterity. *The second recommendation is accordingly that serious transfers of resources from ICs to DCs are essential to quell the ethical conflict between urgent present needs and future possibilities of subsistence.* Malnes' further argument for this recommendation is that even when less than needs are at stake in developing countries, great sacrifices are involved anyway if they are required to lower their economic ambitions in the interests of future generations. A norm which requires such sacrifice is unlikely to be acceptable, and transfers may help assuage such sacrifice.

We also briefly compare Malnes' thesis with the Rawlsian Theory of Justice in the sense that the latter may apply to intergenerational situations. Very briefly, Rawls elaborates the basic idea that the correct principles of justice are those which *free and rational persons, concerned to further their own interests, would agree as defining the fundamental terms of their association in the matter of distribution of the benefits of economic activity, if the agreement were made under conditions that were fair to all parties.* Such a fair position (*"the original position"*) obtains, according to Rawls, when the contracting parties are under a *"veil of ignorance"* about what their respective place and endowments will be in the society they are about to enter. Clearly, this would include ignorance about the generation in which one may be born into, no less than race, nationality, or inherited wealth and privilege.

Rawls claims that the agreement would consist of two principles. The first (the "liberty principle") is that everyone is to have equal right to the most extensive basic liberty consistent with equal liberty for others. Second, that social and economic inequalities are to be arranged so that they are (1) to the greatest expected benefit of the least advantaged members of society (the "difference principle"), and (2) attached to positions open to all. The first principle is lexicographically prior to the second, meaning that tradeoffs of liberty for economic or social advantage are impermissible (no "happy slaves"). Rawls considers the terms *"advantage"* and *"inequality"*, not in terms of utility, but in terms of holdings of *"primary goods".* These include "the basic rights, liberties, and opportunities, income and wealth, and the social bases of self-respect". Rawls apparently sees primary goods as things that any rational person would want more rather than less of *whatever the peculiarities of his life-plan.* The Theory of Justice then involves at least an ordinal ranking of alternative bundles of primary goods, and maximising the index assigned to the least advantaged (representative) individual in society.[39]

The set of primary goods may, of course, include environmental assets. The difference principle would require that any depletion of environmental resources by the present generation (which, *ceteris paribus* would place

[39]Rawls permits some aggregation over societal classes in reckoning "advantage".

all succeeding generations at reduced advantage) can only be justified if each generation gained thereby in terms of their respective holdings of primary goods, the least advantaged generation (which in developing countries may be the present) gaining as much as possible. In other words, the allocation of the benefits of environmental depletion must be shared between the present and succeeding generations. Where this requires that recompense must flow from the present to future generations, priority lies with the generation which may be expected to be the least advantaged.

This conclusion is at some variance with the Solowian notion of sustainability, which also accords with Nozick's Modern Libertarianism. The bequest to the future according to the Rawlsian ethic must be positive, but need not simply equal in value the loss of the environmental resource. Malnes' "needs trump desires" principle is however consistent with this application of the Rawls ethic, if "needs" correspond to situations of lesser advantage than "desires", both reckoned in terms of an index of holdings of primary goods.

5. Some Concepts From Amartya Sen[40]

The previous section presented the Malnes thesis, in which the notions of "subsistence" or "basic needs" and "desires" were central to the principle of "needs trump desires", and the "harm principle", that is obligatory to abjure actions which inflict loss of subsistence to innocent persons for the sake of "desires". Malnes, however, does not furnish an elaboration of these notions, and in this sense the thesis is incomplete. Similarly, Rawls relies on an imprecise notion of "primary goods", an (ordinal) index of whose holdings signifies "advantage".

Both "basic needs" and "primary goods" may involve elements of the third entity, i.e., uncompensable values, in addition to the first and second entities, that we referred to in Section 1. Similarly, notions of sustainability discussed in section 3, may also involve all three entities. Some concepts formulated by Amartya Sen may enable one to capture all these entity values.

Sen asserts that the central question in any evaluative exercise is to distinguish between what is important only as a means, and what is important in itself. Sen conceptualises an antecedent inequality between those possessing and not possessing primary goods, and then focuses on its conversion into *"functionings"* and *"capabilities"* defined below. He finds that an index of primary goods cannot be an index of well-being because of interpersonal variations in what persons can achieve with their holdings of primary goods, depending on their respective social, biological, and other (e.g., climate) parameters, and emphasises the need for a richer informational input to evaluating states and actions, including well-being.

The most elementary concept in Sen's approach is that of **functionings.** Functionings represent components of the state of a person, in particular the various things that he manages to do or be in leading a life. The **capability** of a person is the alternative sets or combinations of functionings the person can achieve, and from which he can choose (any) one set.

Some functionings are elementary, e.g., being adequately nourished, being in good health, etc., and may be strongly valued by all. Others may be more complex, but also widely valued, e.g., "achieving self-respect, being socially integrated". Individuals may differ in the importance they attach to these functionings.

Since the number of possible functionings is extremely large, in any evaluative situation the *relevant* functionings have to be chosen. This choice must relate to the underlying concerns and values, which may lead one to consider some functionings as important, and others as trivial. For example, in evaluating Climate Change impacts, nutrition, social identity (which may be threatened in Small Island States (SIS) due to sea-level rise) are clearly relevant functionings, while opulence is not.

In an evaluative task, one may distinguish between two distinct questions: (1) What are the objects of value? and (2) How valuable are the different objects? The first question must be clearly answered if the second is to be pursued. In addition, the identification of objects of value itself facilitates a **"dominance ranking"**.[41] This dominance ranking can be shown to have standard **"regularity properties"**.[42] This fact alone can take one considerable distance in the evaluative procedure.

The capability approach is concerned primarily with the identification of value-objects, while the evaluative space is the sets of functionings (i.e., capabilities). While this

[40]Sen's writing is extensive. One standard reference is Sen (1985).

[41]**Dominance:** The bundle of valued goods X is at least as good as the bundle Y if it yields at least as much as each of the valued objects, and dominates Y if, in addition, it yields more of at least one of the valued objects.

[42]These include:

(1) **Ordering:** For every pair of technically feasible bundles, X_0 and X_1, one and only one of the following must be true:
- (a) X_0 is preferred to X_1, or
- (b) X_1 is preferred to X_0, or
- (c) X_0 and X_1 are equally desirable.

(2) **Transitivity:** If X_2 is at least as good as X_1, and X_1 is at least as good as X_0, then X_2 is at least as good as X_0.

furnishes the identification of objects of value, it does not furnish the relative values of the objects themselves. Various substantive ways of evaluating functionings and capabilities can belong to the same general capability approach.

The identification of value objects and specifying an evaluative space involve norms, which must be related to the purpose of the evaluation. One may have a fourfold classification of aspects of evaluative interest, based on two types of distinctions. One relates to the distinction between a person's *well-being*, and the pursuit of his overall *agency goals*, which include the goals that the person has reasons to adopt, and may include goals other than personal well-being. The second distinction is between *achievement*, and the *freedom to achieve*. This distinction may be applied to pursuits of both well-being and agency goals, yielding four categories of advantage related to a person: (1) well-being achievement, (2) agency achievement, (3) well-being freedom, and (4) agency freedom.

Assessing these four types of benefit involves different types of evaluative exercise, and can also have different implications for action based on the evaluation. For example, in the Climate Change context, global policy may address the prospect of loss of livelihood due to loss of cropland (well-being deprivation), but not that of loss of personalised transport (an agency goal).[43] Further, well-being freedom may be more relevant for public policy than well-being achievement. For example, global institutions may have reasons to facilitate migration of people from Climate Change impacted areas, but not to insist that they actually move.

This discussion has focused on functionings rather than capabilities. However, according to Sen, the capability set is the primary information base. Why is it necessary to consider capability?

Capabilities are defined by derivation from functionings. Further, the capability set contains information about the actual functioning n-tuple chosen, since it is among the feasible n-tuples. One may be interested not merely in looking at "well-being achievement", but also in "well-being freedom". Additionally, *freedom may be intrinsically valuable*. Acting freely and being able to choose may relate directly to well-being, not just because more freedom may make better alternatives available. Thus, if choosing is seen as part of living, i.e., "doing *X*" is distinguished from "choosing to do *X* and doing it", then well-being freedom need not be independent of the freedom reflected in the capability set.

The capability approach may be employed to furnish substance to Malnes' "basic needs" and "desires", as also Rawls "primary goods".

The former (basic needs and desires) may be conceptualised in terms of a core capability set with functionings such as nourishment, shelter, freedom from disease, literacy, basic public transport and communication, the material bases of culture, etc. comprising "basic needs", surrounded by a penumbral set of other interests, e.g., epicurean food, personal transport, elective plastic surgery, marble floored housing, etc., comprising "desires". The latter (primary goods) may comprise the level of nutrition, literacy rates, life expectancy, morbidity rates, risk of natural disaster, basic political freedoms, etc.

6. Conclusion

This paper is a review of some of the literature that we consider relevant to discussion of inter-generational questions in Climate Change. It also critiques the widely discussed technique of CBA as it relates to intergenerational questions, and its implicit normative basis in utilitarianism, besides an alternative set of principles derived by Malne. Malnes' principles are also contrasted with the application of the Rawlsian ethical norm to Climate Change. What have we sought to achieve in this exercise?

In the first place, we have sought to demonstrate that equity issues are amenable to analysis, and that the premises for such analysis derive from formal ethical theory. Pitting one's subjective ethical preferences against those of others does not usually lead to resolution, and we have attempted to show that "wars of intuition" are unnecessary.

In the second, we have attempted to point to several shortcomings of the CBA/utilitarian framework in its application to inter-generational questions. Apart from its inability to incorporate what we have termed "third entity values", we believe that conventional CBA approaches to inter-generational questions are inconsistent with the utilitarian doctrine itself.

Finally, we have reviewed some concepts due to Sen, which we feel can capture values of entities of all three kinds. While the Sen concepts are not in themselves ethical norms, they are useful in providing substance to some ethical frameworks which are alternatives to CBA/ utilitarianism. By embodying third entity values in the ethical norms by the use of Sen concepts, it may be possible to arrive at more satisfying principles for inter-generational equity.

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[43] Even though individuals may prefer cars to food!

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Climate Change and Future Generations: Do We Care Enough?

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Abstract—Climate change has several implications for intergenerational equity, as it has long-run and irreversible consequences. This paper discusses the economists' views on intergenerational equity, both from a normative and a positive standpoint. The normative side of the analysis is useful to derive criteria which ensure intergenerational equity, while the positive side considers incentives which may or may not lead to equitable outcomes.

1. Introduction

Climate change has several implications on the equity ground. It has to do with horizontal equity, as climate change and mitigation policies affect differently countries and regions. It has to do with intergenerational equity as climate change is a very long-run phenomenon, which implies deep and irreversible consequences. This paper deals with intergenerational equity (henceforth IE).

Equity across generations requires equal treatment of agents born at different points of time; this, in turn, implies a criterion which takes into account the utility of all the generations, without any discrimination. This is not done in any model which discounts the utility of future generations, as the standard growth model.

The issue of discounting and discrimination is becoming more and more relevant to economic theory and policy-makers to the extent that it interconnects strongly with climate change. While in the past the problem had mainly risen in relation with the exploitation of exhaustible natural resources (e.g. oil), now it is used in relation to environmental degradation which touches directly upon the utility of the future generations. It is our contention that the problems raised by climate change make IE even more relevant than before when evaluating the consequences of economic policies.

The paper is divided into six sections. Section 2 provides a definition of IE, while section 3 discusses it with reference to climate change and other environmental phenomena. Section 4 deals with discounting in the Utilitarian framework. Section 5 considers the Rawlsian criterion. Starting from the observation that the above criteria are basically normative, section 6 considers some positive aspects of intergenerational equity, and discusses the scope for further research.

While IE and the issue of discounting seem to be very abstract ones, we would like to point out that they have relevant consequences on the actual policy making. Any calculation of costs and benefits related to mitigation policies, as those carried out in the context of IPCC, are currently based on models and calculations which embody some form of discounting. Even small changes in the discount rate can lead to substantial changes in the policy recommendations. For this very reason it is crucial to experiment with alternative criteria, which are ethically defensible and empirically sound.

2. Intergenerational Equity: A Definition

We define IE by means of a two-period example, with two generations consuming a flow of consumption c_t from a stock A_t, which can be seen as an environmental asset or a natural resource. Therefore $A_1 = A_0 - c_1$, $A_2 = A_1 - c_2$. Consumption of the stock allows for utility u (c), where the utility function has the standard properties. A planner who is considering the problem from the point of view of period 0 would consider maximisation of the following function:

$$\max u(c_1) + \left(\frac{1}{1+\delta}\right) u(A_0 - c_1)$$

where the resource constraint has been substituted in. The scalar $\delta \in [0, 1]$ is the utility discount rate, or the rate of time preference. When $\delta = 0$ the utilities of the two generations are given equal importance in the criterion. For any $\delta > 0$ the utility of the future generation is given less weight, and may give rise to lack of IE. From the necessary conditions for maximisation of such a function, $u'_{c1} = \left(\frac{1}{1+\delta}\right)u'_{c2}$, it is clear that consumption (and utility) is constant across generations only if $\delta = 0$, i.e., with no discounting. The larger is δ, the lower is the share of the stock left over for the future generations, the lower is the ratio between future and current utilities.

The literature has spent many efforts in discussing the logic of discounting. The discounting practice has been objected to by several authors in the history of economic thought, first of all Ramsey (1928), who claimed that attaching a lower weight to the utilities of the future generations arises "merely from the weakness of the imagination". Nevertheless, most of the economics literature has been cast in the framework of a model where the agent does attach a lower weight to future utility. Why is that?

The answer is connected with the choice of the time horizon over which to devise policies. In the simple two-period example given before it is of course not necessary to consider $\delta > 0$, but then the relevant question is: Why two periods? How do we know there is no need to plan for the further future? In fact, to the extent that an infinite horizon seems more natural, it becomes necessary to consider a positive discount rate to maintain a finite value of the sum of all future utilities,

$$\sum_{i=0}^{\infty} \left(\tfrac{1}{1+\delta}\right)^i u(c_{t+i}), \text{ or } \int_0^{\infty} e^{-\delta t} u(c_t)dt$$

in the continuous time formulation. Such objective functions are well-defined only if a positive discount factor forces the sum to converge to a finite number. Lacking such convergence, many programmes may yield a sum of utilities that is equal to infinity, and there is no way to choose among them. It therefore follows that problems related to discounting in the context of analytical models arise because of impossibility to choose a final date for the planning horizon; moreover, problems would be solved only if such a date corresponded to extinction of the system under consideration, since otherwise there would be a problem of attaching a value to the stocks that are left at the terminal date of the planning period, which would by itself require an evaluation of what happens after the end of the planning period.

In fact, stochastic elements related to uncertainty about the survival of the system under consideration are one way to give discounting a proper micro-economic justification. This is done in two frameworks: The first is explored in the papers by Dasgupta and Heal (1974), Dasgupta et al. (1976) and Beltratti et al. (1992), where it turns out that including some stochastic elements into the model, for example the possibility of finding backstop technologies or changing preferences, is equivalent to augmenting the discount rate in the deterministic problem for a certainty-equivalence property. The second is the Yaari-Blanchard framework based on continuous time overlapping generations, where each agent discounts the future at a rate which includes the instantaneous probability of death, see Calvo and Obstfeld (1988). In both cases one may assume a very tiny pure rate of time preference for the sake of writing down the model as a discounted utility problem and being able to apply the standard solution techniques, but then augments such a discount rate with a certainty equivalent term which becomes the true motivation for discounting.

3. The Environment and Intergenerational Equity

Even though the problem of IE can be described in general terms as a decision about the use of resources at different points in time, that is how much is saved and how much should be invested out of the production obtained from a given capital stock, it should be recognised that its relevance is particularly visible in discussing allocations of natural and/or environmental assets. Exhaustible resources are a good example: Their use on the part of the current generation is clearly a deduction from the use of future generations, and as such poses a problem of equity.

Is the use of environmental resources, e.g. atmosphere, also part of the equity problem? The answer depends crucially on the degree of reversibility of their use, and of the time lags necessary to bring the stock to the original state. It is true that marine pollution and deforestation are phenomena that in principle can be reversed by cleaning up or by stopping the cases of overuse of the resource; however, the time which is necessary to achieve purification and reforestation can be very long, and the costs can be extremely high. Moreover in practice high degrees of marine pollution and deforestation affect the ecological system in ways that are totally irreversible, causing the extinction of species which cannot live in the new polluted habitat. In other cases, matters are even worse: Each year six million hectares of productive dryland are turned into desert, turning such a resource from the class of reproducible to that of non-reproducible assets.

Global warming and climate change is another example of contrasts among generations: The current generation reaps the benefits of economic activity and increases the concentration of gases that might change the climate with a permanent negative impact on welfare of future generations. This phenomenon raises new concerns to the extent that it adds an important dimension of uncertainty: the very existence of the issue is under consideration, and its consequences are highly uncertain, both from a climatic and from an economic point of view, see Cline (1992), Cox (1991) and Lave (1991); Heal (1984) presents an early interesting modelling attempt where economic activity affects the probability of the climate change. Moreover, only coordinated international action among large industrialised countries may take useful actions; a voluntary decrease of emissions of a single country is useless given the public goods nature of the atmosphere.

Finally the economic consequences of environmental phenomena are long-lived, due to the characteristic of environmental assets to yield services for a long period of time. Excessive use of a resource deprives many (possibly all) future generations of a highly valuable income, which in some cases cannot be substituted with other assets. If current economic activity is pushed to the extent of causing a permanent change in the climate, the damage to future generations may be unwieldy large.

4. Decreasing the Discount Rate

If on the one hand the main problem with discounting is discrimination of future utilities, and if on the other hand discounting is necessary for the comparison of different policies, could not one use a very low discount rate, or even better the limit of the solution for the discount rate tending to zero? This section gives three examples of why this may not be appropriate:

- In endogenous growth models there are solutions with permanent growth (see Romer, 1990), where the rate of growth of consumption g depends on the difference between the marginal productivity of capital ρ (also equal to the interest rate) and the rate of time preference δ, given the elasticity of marginal utility $\eta, g = \frac{\rho-\delta}{\eta}$. The equation shows that decreasing the rate of time preference is going to increase the rate of growth of consumption, and therefore is going to increase the saving ratio of the current generation to the benefit of the future. This policy amounts to increasing intergenerational differences in utilities. Moreover, from the point of view of the solutions of the models, a lower bound on the rate of time preference is required to preserve finiteness of the integral of utilities given a positive rate of growth of consumption. In this setting, decreasing the discount rate is not always possible, and not even desirable for achieving IE.
- In a standard cake-eating problem one has to devise the best rate of consumption of an exhaustible resource. Under a utilitarian criterion, the optimal rate of change of consumption over time is equal to $g = -\frac{\delta}{\eta}$ (see Heal (1993) for a general review). The limit of this solution as the discount rate tends to zero, implies a consumption level which is close to zero and declines very gently over time. In some sense, solutions corresponding to lower rates of discount are more equitable. However, the solution to the problem of consuming a cake from the point of view of IE implies no use of the resource. The only solution which maintains perfect equity for an infinite population is the one in which nobody consumes any portion of the stock. There is a discontinuity in the policies suggested by a tiny discount rate and a zero discount rate.
- Finally, decreasing the effective discount rate may even lower the welfare in a second-best condition where there are some market failures. In some cases, as the discount rate goes down, the difference between the private and public solutions increases, by making the externality problem even worse. This may, for example, be due to the fact that a lower rate of discount increases patience and the equilibrium marginal productivity of capital, increasing investment and the capital stock. To the extent that a larger capital stock puts more pressure on the use of resources, a lower quality of the environment may result, see Krutilla (1967) and Krautkraemer (1986). The relative welfare of the decentralised and the centralised solutions may decrease, leaving the market economy in an even worse situation. In a second-best world, the government has to correct for the market externalities before correcting for discrimination against the future.

5. The Rawlsian Criterion

If decreasing the discount rate cannot be recommended as a valuable general strategy, one has to start the quest for alternative criteria, see Koopmans (1967) for a synthetic review. The best known alternative has been formulated by Rawls (1971), who suggested maximising the utility of the least advantaged generation (see Dasgupta and Heal (1974) for a general review and comparison with other criteria) in order to reach a situation where utility is constant from one period to another.

The plausibility of the solutions suggested by the Rawlsian criterion is highly model-dependent: Solow (1974) showed that the Rawlsian criterion applied to a one-good economy described by a standard production structure of the type $\dot{K}_t = F(K_t, L_t) - C_t$ predicts a solution that never leaves the initial conditions, $C_t = F(K_0)$, for any $t \geq 0$. Generation 0 can well save and increase the future stock of capital, but this would decrease immediate utility without any possibility of compensation from the future to the present. This solution is not very satisfactory, from both a descriptive and normative point of view. However, in the same paper Solow shows that such a "degenerate" policy does not necessarily hold if one modifies the specification by adding a flow of natural resource r in the production function, $Y_t = F(K_t, r_t)$. In this case the sacrifice of the present in terms of accumulation of capital is compensated by a larger use of natural resources that may yield consumption goods: there are trading opportunities between the present and the future. The resulting dynamics is complicated and not very intuitive, see also Asako (1980), who considers a model where agents derive utility $u(c, P)$ from consumption c and disutility from a stock of pollution P that is increased over time by production, $\dot{P}_t = g(k_t) - hP_t$. In this case the increase in consumption goes with the increase in pollution, and the Rawlsian criterion suggests a way to balance the two in order to maintain utility constant.

At a more easily interpretable level, Hartwick (1977), in the context of the same model considered by Solow, shows that the solution is simpler if one is concerned with a path maintaining a constant level of consumption, without necessarily looking for the one with the largest consumption. Hartwick finds that society may maintain forever a constant level of consumption as long as there is net investment in physical capital which equals the rent obtained from extraction of exhaustible resources, $\dot{K}_t = \frac{\partial F}{\partial r} r_t$. In the Cob-Douglas case considered by Hartwick, $Y_t = K_t^{\alpha} r_t^{1-\alpha}$, the rule therefore calls for $\dot{K}_t = (1-\alpha) Y_t$ that is a constant investment-output ratio, which, given constancy of consumption and output, implies a constant investment over time. This rule is simple and intuitive, even though it is based on a constant saving rate which may not be compatible with the choices made by optimising agents (subsequent contributions have further examined Hartwick's Rule, by pointing out its connection with the concept of a regular maximin path, introduced by Burmeister and Hammond (1977). See Dixit et al. (1980)).

Two problems may prevent the wide application of the criterion:

- The dynamic paths may be difficult to obtain in market economies. Becker (1982) has shown that one can find a regular maximin path which can be sustained as a competitive equilibrium as long as it is possible to implement a system of effluent charges, environmental rental charges and lumpsum transfers which is however very complicated and requires a knowledge of the structure of the economy which is not likely to be possessed by the central authority.
- The second problem comes from the lack of intertemporal consistency of Rawlsian programmes. Dasgupta (1974) and Calvo (1978) show that generations which manifest altruism towards future generations will deviate from equitable plans decided by previous altruistic generations.

6. Normative Models and Positive Theory

The models and criteria recalled so far are primarily normative, as they provide guidance for a benevolent intergenerational planner. If we move to the positive level, and analyse the economic incentives that lead agents to implement a certain criterion, we run into serious problems.

In the absence of an equitable intergenerational planner, the intertemporal allocation of environmental and natural resources (and the related costs) can be characterised as a game among generations, just like horizontal allocation can be seen as a game among countries.

The difference with horizontal allocation, however, is substantial. In the intertemporal game one set of players, namely future generations, is simply missing and has no representation in current decisions.

In a positive setting, the present generation has necessarily dictatorship over the future. And this situation obviously leads to "bad" allocations unless the present generation cares about future generations and adopts an equitable criterion. Let us conventionally call this attitude "ethics", and define "ethical" an agent or a population that cares about future generations.

The previous remark leads to a crucial point: in a positive setting, there is no intergenerational equity without ethics.

This can be seen as a negative result. But it can also be seen as a starting point for further research. As is well known, some theorists (e.g.

Amartya Sen) have long been working on ethics, and claim that it is crucial for the normal working of market economies.

We believe that some degree of ethics exists in our societies and systems of values (in some more than in others). We could also provide some examples of it. But from the economist's point of view the relevant question does not concern so much the existence of ethics, but how to transform it into decisions which implement equity.

In this area, we believe there is much to be gained by orienting our research and policy analysis in some specific directions.

First of all, we should work in designing appropriate institutions that implement intergenerational equity when at least one share of the population is ethical. We are thinking of mechanisms that prevent free riding by the few, voting systems and public choice mechanisms which favour long run considerations; education and the diffusion of information.

Over and above research on institutions, we also recommend applied work to highlight rules of the thumb which are somehow robust to changes in models and key parameters.

Finally, we would like to conclude with a plea for the preservation of cultural diversity. In several cultural systems (the Catholic, the Buddhist etc.), intergenerational equity is a deep-rooted value. One cannot say the same of the simplistic version of homo oeconomicus, which admittedly is strictly self interested. The latter assumption is convenient and fruitful from the theoretical point of view. But it should not be taken as a recommendation or a guidance for the design of society and educational systems, as homo oeconomicus appears to be unsustainable in the presence of environmental resources. Different cultural systems seem to be superior in the sustainability dimension, and this should start a reflection by the advocates of totally unregulated societies.

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The Global Climate Policy Evaluation Framework*

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Abstract—The prospect of climate change confronts policy makers with difficult choices. The climate change issue is enormously complex, and involves significant physical, social, and political interactions, large uncertainties, potentially serious environmental effects, and significant costs of management. Yet, policy makers must somehow cope with this complex array of issues and uncertainties to make policy decisions today. Unfortunately, two extreme views have emerged, one arguing that society should do nothing until the key uncertainties have been resolved, the other that it should do everything possible to avoid the potential catastrophic outcomes. Policy makers must move beyond these two views to make wise and informed choices from a wide array of alternatives.

The Policy Evaluation Framework (PEF) is a decision analysis tool that enables decision makers to continuously formulate policies that take into account the existing uncertainties, and to refine policies as new scientific information is developed. It is designed to provide a framework for integrating and evaluating the best available information from the diverse elements that influence climate policy. PEF encourages exploration of the policy implications of alternative technological, economic, physical, and biological assumptions and scenarios.

PEF integrates deterministic parametric models of physical, biological, and economic systems with a flexible decision tree system. The deterministic models represent greenhouse gas emissions, atmospheric accumulation of these gases, global and regional climate changes, ecosystem impacts, economic impacts, and mitigation and adaptation options. The decision tree system captures the key scientific and economic uncertainties, and reflects the wide range of possible outcomes of alternative policy actions. The framework contains considerable flexibility to allow a wide range of scientific and economic assumptions or scenarios to be represented and explored.

A key feature of PEF is its capability to address both mitigation policies and investments in anticipatory adaptation to protect ecological and economic systems, as well as interactions among such options. PEF's time structure allows issues related to the timing and flexibility of alternatives to be evaluated, while the decision tree structure facilitates examining questions involving the value of information, contingent actions, and probabilistic representations.

This paper is intended to introduce PEF to the global climate policy community. The paper provides an overview of the structure, modules, and capabilities of PEF, and discusses selected results from an initial set of illustrative applications. Fuller descriptions of the PEF methodology and results can be found in the EPA's forthcoming "Integrated Assessment of Global Climate Change" (EPA, in press) and "The Global Climate Policy Evaluation Framework" (Chan et al., in press).

Introduction and Overview

The US Environmental Protection Agency and Decision Focus Incorporated developed the Global Climate Policy Evaluation Framework to provide decision makers with a tool to evaluate policy alternatives associated with global climate change, while explicitly recognising and addressing the existence of considerable uncertainty and scientific debate surrounding climate issues. PEF is an integrated assessment tool that allows policy makers to consolidate information from multiple disciplines into a single framework. It has particular strengths that allow decision makers to address immediate policy issues, including investments in mitigation and anticipatory adaptation[1] options, the timing of policy actions, the implications of climate change

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[1]Adaptation is defined as actions taken to protect ecological or economic systems from climate change. It is divided into anticipatory adaptation, spending in advance of observed climate change, and reactive adaptation, spending in response to climate change. Anticipatory adaptation may reduce damages either by directly reducing the sensitivity of ecological or economic system to climate change, or by replacing reactive adaptation with more effective anticipatory adaptation.

for ecological and economic systems, and the question of insuring against uncertain but potentially significant future damages.

PEF is designed to help investigate and answer questions such as:

- When should society act? What are the benefits of keeping options open?
- What are the interactions between mitigation and adaptation policies?
- Are additional actions justifiable as insurance against uncertain future climate changes?
- What are the policy implications of thresholds or irreversibilities in ecosystems or the economy?
- What are the top priorities for future research?

By addressing the uncertainties in physical, biological, and economic systems explicitly, PEF allows policy makers to move beyond the polarised debate in which some argue that society should delay action until the many scientific uncertainties have been resolved, while others argue that the potential outcomes are so catastrophic that society should do everything possible to mitigate climate change. PEF is an integrated model that combines mitigation, adaptation, emissions, climate, economic sectors, and ecosystem effects into a single framework. It is flexible enough to represent virtually any combination of policy options, scenarios, assumptions, and specifications of key relationships. It is efficient enough to evaluate numerous combinations of policy options and scenarios. Both its relationships and its capabilities will continue to evolve as new information becomes available, and new needs arise.

PEF's structure combines two components: (1) a deterministic model that describes the physical, biological, and economic impacts of greenhouse gas emissions; and (2) a decision tree system that organises relevant information about the decisions and uncertainties. These components support the analytical tools that make it possible to evaluate policy alternatives under uncertainty. Figure 1 shows the relationship between PEF's deterministic model and its decision tree. For a given set of assumptions, a specific physical and economic scenario, and a particular policy decision, the deterministic model calculates the resulting physical and economic impacts. The decision tree executes the deterministic model multiple times to evaluate the effect of various uncertainties and decisions.

The PEF framework may be divided into three levels:

(1) The *overall structure* as a decision analysis tool with a decision tree and a deterministic model;
(2) The *specific equations* used in the deterministic model in an application of the framework;
(3) The *numerical assumptions* used as inputs in any specific set of analyses.

Both the deterministic model and the decision tree were designed with considerable flexibility to address a wide range of scenarios, options, and levels of detail, and to easily update relationships and assumptions in light of new information. The equations comprising the deterministic model are likely to evolve periodically as further research becomes available. The specific numerical assumptions can be changed readily to enable

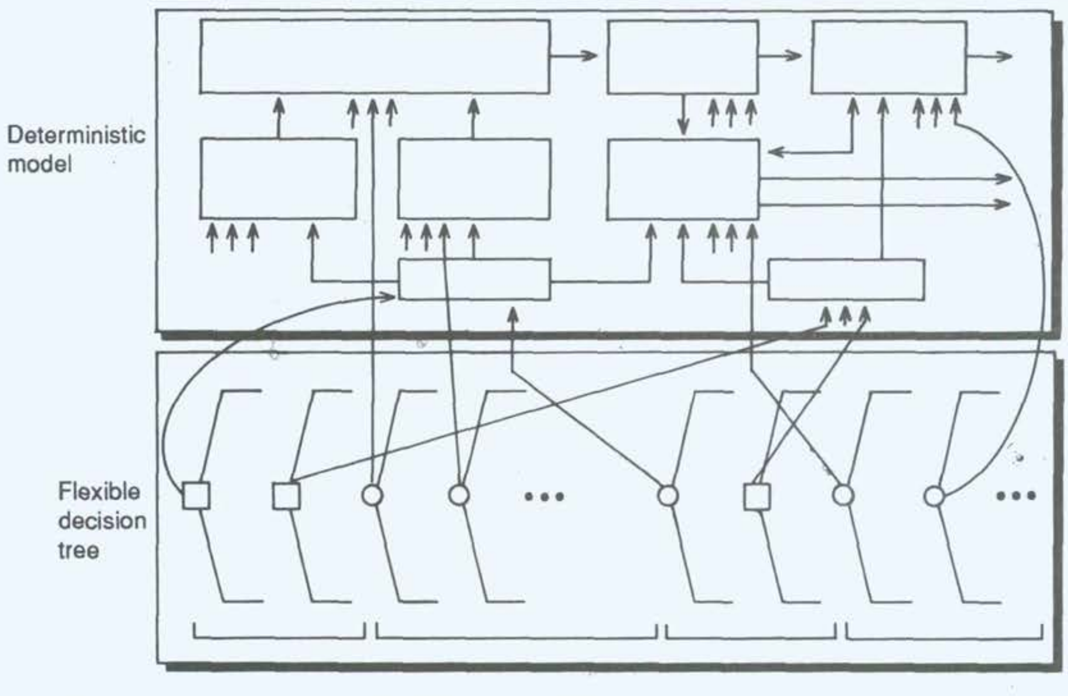

Fig. 1. Relationship between the deterministic model and the decision tree.

any set of assumptions and scenarios to be studied.

The scope of the framework includes both economic and ecosystem impacts, and both near-term and long-term adaptation and mitigation decisions. The near-term decisions are the primary focus of the model; the long-term decisions are included to provide a more realistic model of the consequences of near-term decisions, and to investigate the implications of the timing of actions.

Deterministic Model

PEF's deterministic model calculates the impacts of climate change given a set of policy alternatives and a single scenario for each input parameter. PEF provides the ability to disaggregate impacts by geographic region, economic sector and ecosystem type. The calculations within the deterministic model are divided into a series of modules:

- US emissions
- Rest-of-world emissions
- Atmospheric processes and global climate
- Regional climate
- Economic impacts
- Ecosystem impacts.

Figure 2 illustrates the deterministic model's structure.

Designing the deterministic model required tradeoffs between the detail of physical and economic representations and the simplicity needed for a practical analytical tool that can be used to rapidly evaluate an array of policy options and scenarios. This type of structure provides transparency, which also helps policy makers understand and interpret the results. For most processes, the model represents the physical relationships with parametric equations that can be calibrated to the results of larger, more detailed models. This approach provides the flexibility to represent many differing assumptions, opinions, or results. As PEF evolves, various relationships in the deterministic model will be updated to reflect new information.

The deterministic model uses reduced form models where it is appropriate to do so—that is, where the key aspects of the underlying phenomena are relatively well understood. The atmospheric process and global climate relationships, for example, use this approach. Where there is not yet a good understanding of the underlying processes, or where it is not reasonable to represent these processes with a reduced form model, the deterministic model uses structured functional forms. The economic impacts and ecosystem impacts relationships, for example, use this approach. All modules include enough parametric flexibility to represent, or to bound, any reasonable scenario. This capability allows sensitivity analyses to help prioritise refinements of the model. Each module is described below.

Mitigation and Adaptation Decisions

The current version of PEF includes first- and second-period mitigation and adaptation decisions. The model considers all combinations of alternatives. For example, selecting a first period mitigation alternative does not limit the range of first-period adaptation alternatives available, nor does it limit the range of second-period mitigation or adaptation alternatives available. Each period's decision may include up to six different mitigation and six adaptation alternatives.

An individual mitigation alternative includes the target reductions in US and rest-of-world emissions over time for each greenhouse gas. The realised reductions, as a percentage of the target reductions, are specified separately for US and rest-of-world emissions. Each alternative may also include the cost of the alternative, or the cost can be estimated using an endogenous model in PEF. Although PEF can estimate

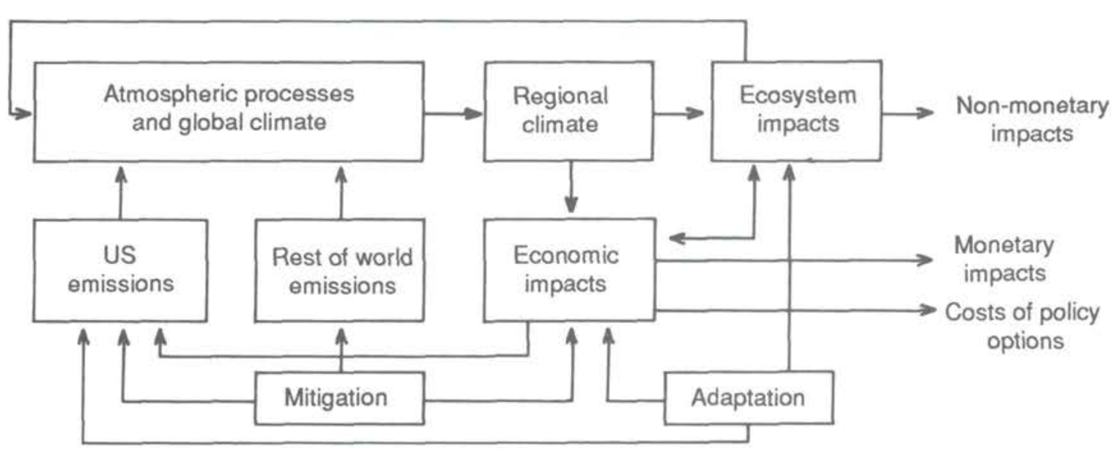

Fig. 2. Overview of PEF's deterministic model.

reductions in any greenhouse gas, the cost model currently estimates only the cost of carbon dioxide reductions. If an alternative scenario includes reductions in other gases, the cost of those reductions must be specified. This structure makes it possible to incorporate the cost and efficacy of mitigation from other models or studies.

A particular adaptation alternative includes four components: the dollar investment in economic adaptation by sector over time; the dollar investment in protecting ecosystems (ecosystem adaptation) by ecosystem type over time; the allocation of each sector's economic adaptation investment across the regions; and the allocation of each ecosystem type's adaptation investment across the regions. Adaptation alternatives may differ both in amount and timing of spending. In PEF, the cumulative investment, less depreciation, can reduce the impact of climate change on the economy and on ecosystems. The spending is expressed in annual rates of spending in billions of constant dollars. The parameters that describe the effect of adaptation on the impacts and the rate at which the adaptation investment depreciates are specified separately.

US and Rest-of-World Emissions

Although they are distinct modules, the US and rest-of-world emission modules are described together because their structures are identical. PEF can treat US and rest-of-world emissions separately, or it can treat them together by including the US emissions with the rest-of-world.

Given a particular mitigation alternative, with its associated emissions reductions, the emission modules estimate the annual emissions from US and rest-of-world sources of each gas. Emissions are built up from the baseline emissions scenario, the target reduction due to mitigation, and a parameter representing the efficacy of mitigation.

PEF provides several alternatives in selecting the gases to include in an analysis. The model includes specialised atmospheric process relationships for carbon dioxide, methane, and nitrous oxide. Carbon dioxide can be modelled alone or with these other gases. Beyond these, PEF can include any other gases as well, such as CFCs or HCFCs, that fit into the standard relationships described below. The mitigation alternatives may address any of these gases.

Atmospheric Processes and Global Climate

The atmospheric processes and global climate module calculates the changes in global average temperature and average sea level from the emissions of greenhouse gases. As Fig. 3 shows, the module calculates several intermediate steps between emissions and temperature and sea level changes. In the most detailed analyses, the concentrations, equilibrium and realised temperatures, and sea level can be reported at each time increment.

The module uses the Maier-Reimer and Hasselmann model, as described by Wigley (1991), for future carbon dioxide emissions, while it uses a single-sink decay model for past carbon dioxide emissions and for all emissions of other gases. The module uses the IPCC radiative forcing relationships (IPCC, 1990) to calculate radiative forcing directly from the concentrations of greenhouse gases. Following the IPCC (1990), it assumes a linear relationship between changes in radiative forcing and the equilibrium temperature. It uses a parametric model to describe the relationship between equilibrium and realised temperature, which treats each increase in equilibrium temperature as a pulse that becomes realised over time. A parametric model, based on STUGE (Wigley et al., 1991), is used to calculate the change in global sea level.

Regional Climate

PEF's regional climate model calculates regional changes in temperature, precipitation, and runoff from the changes in global mean temperature. In addition, it provides the global changes in sea level and carbon dioxide concentration as inputs to the impact modules.

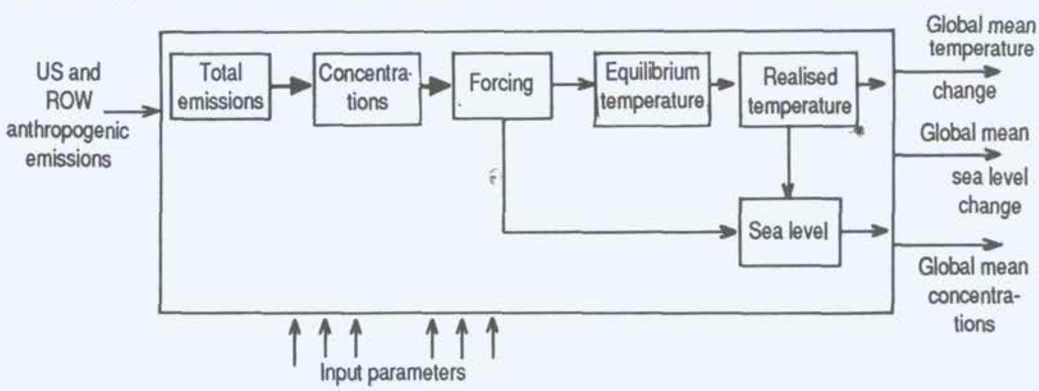

Fig. 3. Atmospheric processes and global climate module.

The choice of regional climate variables is driven by the requirements of the damage functions. The model can be easily expanded to meet the requirements of the economic damage functions and the ecosystem failure relationships (described below) as they evolve.

General circulation models still offer little insight into the nature of regional changes in temperature and precipitation, runoff, and soil moisture. PEF therefore provides flexible general relationships for regional changes, so that the sensitivity of analytical results to different assumptions about regional climate effects can be explored. The existing structure includes separate variables for each of the regional climate indicators to allow analyses of the influence of an individual indicator and the value of resolving its uncertainty.

Economic Impacts

This module calculates the monetary impact of climate change and the cost of policy actions from the adaptation and mitigation policies and from the regional climate indicators. The module calculates impacts by sector in each region, using up to fifteen sectors in up to ten regions, accounts for adaptation, and estimates the annual damages.

Economic impacts are those that would typically appear in GDP calculations or other monetised economic measures. In general, the economic impacts include effects on activities that take place within economic markets, or on goods that are exchanged on economic markets. The model also places a monetary value on the ecosystem impacts, wherever possible. These generally are effects that are not manifested in markets.

PEF allows spending on both ecosystem and economic adaptation to influence the economic impacts. Spending is accumulated into a stock of investment, which depreciates at a rate determined by an input variable. Adaptation spending targeted at ecosystems are also allowed to affect the economic sector through cross-effect parameters. The cross effects of ecosystem adaptation may increase or decrease the economic impacts. The savings due to economic adaptation are a function of both the adjusted stock of adaptation investment and the impacts before adaptation. Both the depreciation rates and the efficacy of adaptation may vary across sectors.

PEF assumes that the total impacts to a sector can be estimated by adding the impacts due to temperature change, precipitation change, and the other climate indicators. It could, however, be modified to include interaction terms between climate indicators. Damages may be estimated using any combination of linear functions, power functions of arbitrary power, logistic functions, and step functions. PEF uses a separate set of parameters for each combination of sector, region, and climate indicator.

The model does not address reactive adaptation explicitly. Instead, the damages in each sector are meant to represent the impacts of climate change, net of the impacts of reactive adaptation. Anticipatory adaptation may reduce damages either by reducing the sensitivity of an economic sector to climate change or by reducing the need for reactive adaptation with more effective anticipatory adaptation.

Ecosystem Impacts

Very few models exist to guide the initial development of the ecosystem impact module. As a result, PEF uses a simple model which is divided into three processes: estimating the fractional loss of each type of ecosystem by region; estimating the value per unit area lost by region and ecosystem type; and calculating the annual (monetised) impact by region and ecosystem type.

In estimating the fractional loss of ecosystems, the model assumes that changes in climate make some fraction of the ecosystem valueless. This could represent total failure of some fraction of land that had been populated by a particular type of ecosystem, or it could represent a partial loss of all of the land of that ecosystem type within the region.

Once the model has estimated a fractional loss, it then uses a valuation function to estimate the value per unit area by type and region. As with the economic impact module, any combination of linear, arbitrary power, logistic, and step functions can be used to estimate the ecosystem damages. This would allow, for example, the value per acre of a particular type in a given region to increase sharply as the ecosystem becomes scarce. Similar to the economic impacts module, adaptation investments may be made to reduce the amount of ecosystem damage. Ecosystem adaptation is modelled in the same way as economic adaptation, with a stock of investment, depreciation, efficacy of adaptation, and cross effects from economic sector investments.

In the final step, the model combines the area lost, the valuation per acre, and the level of economic and ecosystem adaptation into an annual impact, measured in dollars, of ecosystem or non-monetary damages. This version of the model, while crude, can perform "what-if" analyses regarding non-market impacts to provide useful policy insights. Despite its simplistic nature, this model represents an improvement over those that ignore the potential non-market impacts of climate change.

Time Structure

The time horizon for an analysis, which is specified by the analyst, determines the beginning and end of the period for which impacts are calculated. Within this horizon, PEF's current structure contains two points at which decisions are made. The first set of decisions occurs at the beginning of the time horizon, while the second set may occur at any point within the time horizon. The beginning of each time period, the time step between calculations, and the end of the horizon are user-specified.

Relating this to the levels described in the overview, the use of two decision periods is part of level two and is embedded in PEF's relationships. As such, it could be changed, but not on a regular basis. The beginning and end of the horizon, and the length of the time step, are part of level three and thus can be changed from run to run. Table 1 describes the specific timing assumptions embedded in the current version of PEF.

Decision Tree and Analysis Capabilities

While the core mathematical relationships representing physical and economic processes are located in the deterministic model, linking the deterministic model with a decision tree enables a wide variety of analyses to be carried out. Policy evaluation can be thought of as two interrelated processes: comparing different alternate actions based on cost, effectiveness, impacts, etc., and determining the effect of important uncertainties on physical and economic impacts and on the choice of preferred policies. The decision tree facilitates both processes by selecting and executing appropriate runs of the deterministic model, compiling the results, and presenting the information concisely.

PEF provides a range of built-in analyses, which can be subdivided into deterministic and probabilistic analyses. Deterministic analyses investigate the preferred policy options under various climate and impact scenarios. Probabilistic analyses use the likelihoods of different outcomes to evaluate appropriate options under conditions of uncertainty. Concise descriptions of each of the analysis types are provided in Table 2.

Table 1. Summary of specific timing assumptions

- All variables that do not represent flows (e.g., concentrations of GHGs, cumulative changes in climate indicators) are observed at the beginning of the appropriate period.
- Impacts are discounted to the beginning of the planning horizon.
- All emissions occur at the beginning of each year, and the annual rate of emissions grows linearly between observation points.
- Concentrations, radiative forcing, and all climate indicators are observed at the beginning of the observation period, just before that period's emissions occur.
- Economic and ecosystem damages grow geometrically between observation points.
- Mitigation and adaptation spending occurs uniformly throughout the time step period.
- Adaptation spending adds to the stock of adaptation investment at the end of the time step period, so it has no effect and does not depreciate during the period in which it occurs.

Table 2. Summary of analysis types available in PEF

Analysis type	Variables	Treatment of policy decisions	Output	Key uses
Single path	Fixed	Fixed	Climate and impact values over time	• Validate assumptions
Deterministic sensitivity	Varied individually across range	All combinations used	Present values of impacts for all combinations evaluated	• Identify sensitivity of impacts and decisions to uncertainties
Probabilistic analysis	All combinations used	All combinations used	Expected present value	• Estimate the values of resolving key uncertainties • Identify preferred alternative actions under uncertainty • Estimate the range of outcomes associated with combinations of alternatives

Illustrative Results

This section describes some illustrative results derived using PEF, based on a set of assumptions that treats the US in aggregate, with a single geographic region, economic sector and ecosystem type. While disaggregated analyses are underway, these preliminary analyses illustrate some insights that PEF can provide. More detailed analyses and insights drawn from PEF are described in the EPA's forthcoming "Integrated Assessment of Global Climate Change" (EPA, in press).

How do Mitigation and Adaptation Strategies Depend on Uncertainties?

The most basic issue that PEF can address is the relationship between uncertainties and the preferred levels of mitigation and adaptation. An interesting question regards how preferred strategies change under various climate scenarios. Figure 4 shows realised temperature paths that results from various combinations of doubling temperature and temperature lag scenarios. (The temperature lag describes the rate at which increases in equilibrium temperature become observable.) Figure 5 shows the preferred long-term mitigation and adaptation strategies under the three doubling temperature scenarios. At this point, the value of the analyses is not primarily in determining a single correct policy to implement, but rather in evaluating the potential effects of uncertainties on appropriate decisions. Uncertainty in the climate scenario, by itself, affects the preferred level of action: As the climate scenario becomes worse (more rapid change), more action is warranted.

The preferred alternatives are also strongly sensitive to the impacts scenarios. Figure 6 shows PEF results for appropriate mitigation and adaptation policies under combinations of economic sensitivity scenarios. (The scenarios are defined by the impacts, as a percentage of gross domestic product, that result from a 2.5°C increase in realised temperature.) Although these results are preliminary, they suggest that uncertainties in the impacts resulting from a

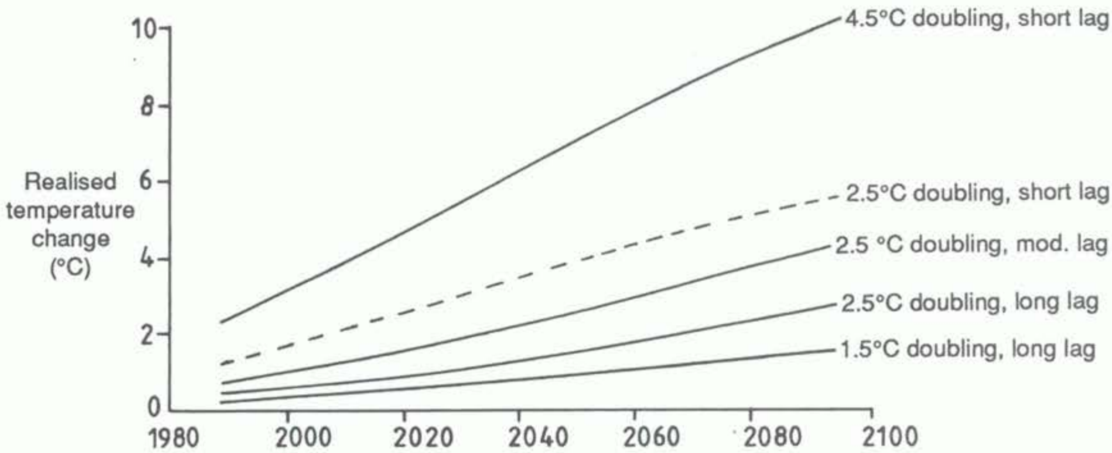

Fig. 4. Realised temperature paths under various combinations of doubling temperature and temperature lag scenarios.

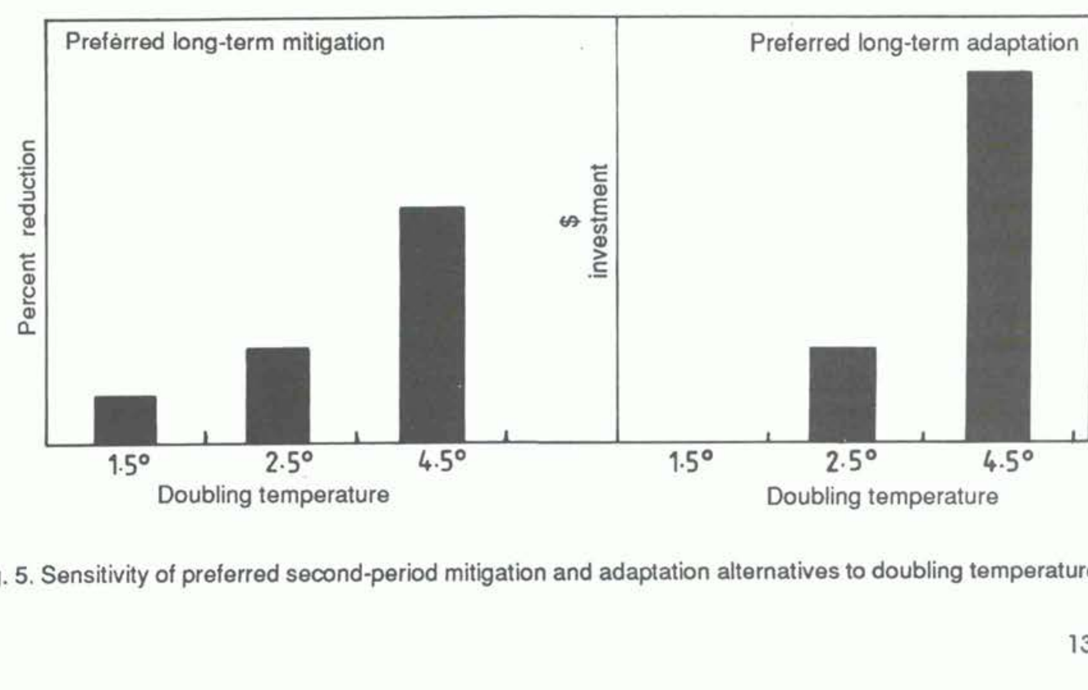

Fig. 5. Sensitivity of preferred second-period mitigation and adaptation alternatives to doubling temperature.

given level of climate change may be as important to policy decisions as the uncertainty in the extent of climate change itself.

How do Mitigation and Adaptation Strategies Interact?

In addition to investigating the sensitivity of policies to uncertainties, PEF can provide insights into the interaction between policies. The left panel in Fig. 7 shows the preferred long-term mitigation, under the best-guess assumption and scenarios, for differing levels of long-term adaptation spending. Similarly, the right panel shows the preferred long-term adaptation level for differing long-term reduction rates. The preferred level of mitigation is sensitive to the preferred level of investment in adaptation, but the preferred level of adaptation is less sensitive to the preferred level of mitigation.

Because mitigation and adaptation work through different mechanisms, they interact asymmetrically. Whereas investment in adaptation are directly targeted at the impacts, investments in mitigation reduce impacts indirectly through changes in the climate. Therefore, while potentially more expensive, adaptation could have larger effects on impacts more quickly. Thus, mitigation becomes less cost-effective when high levels of adaptation investment reduce the impacts, while adaptation is still effective in the presence of high levels of mitigation.

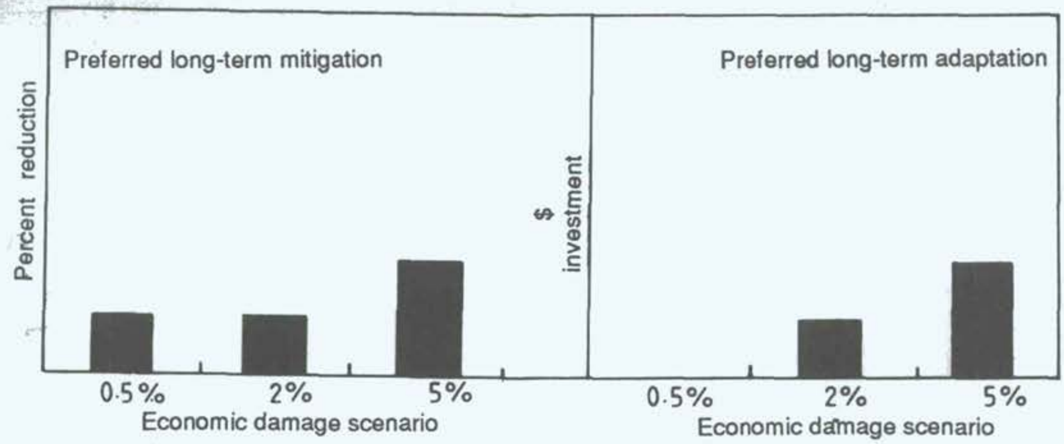

Fig. 6. Sensitivity of preferred second-period mitigation and adaptation alternatives to economic sensitivity scenarios.

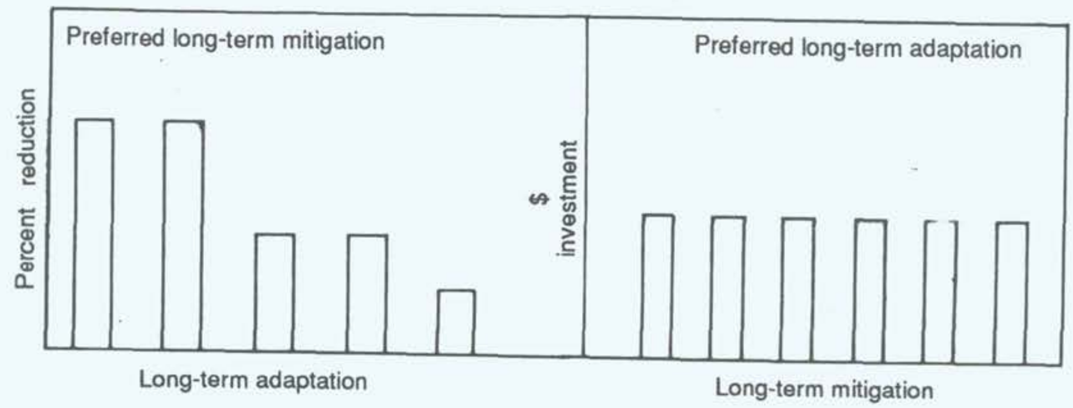

Fig. 7. Interaction between preferred mitigation and adaptation alternatives.

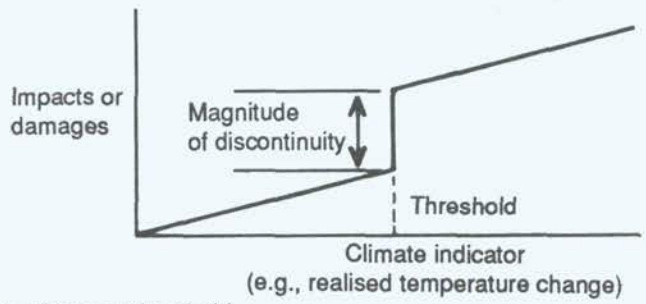

Fig. 8. Example of impact threshold.

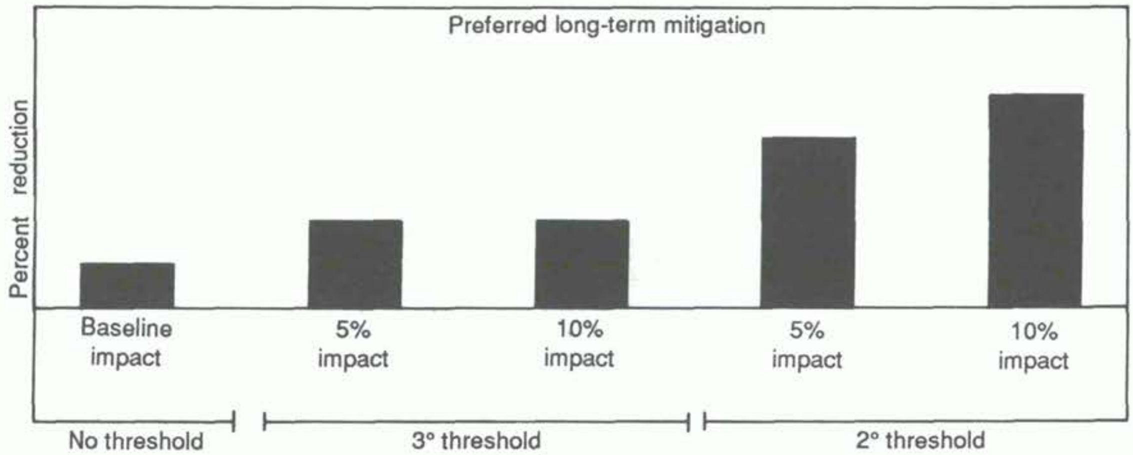

Fig. 9. Sensitivity of preferred second-period mitigation alternative to threshold characteristics.

What are the Implications of Thresholds?

Physical, biological, or economic systems may exhibit threshold behaviour, experiencing sharp changes in response as driving factors cross thresholds. This could happen, for example, as species become extinct, or as increases in sea level overwhelm coastal defenses. These scenarios are modeled in PEF using a threshold function like the one shown in Fig. 8.

Figure 9 shows the preferred long-term emission reductions for different threshold scenarios. The results to date suggest that the preferred reduction in emissions is more sensitive to the time at which the threshold occurs than to the magnitude of the impacts.

Conclusions

The Policy Evaluation Framework provides a flexible and powerful tool for policy makers. PEF's design evolved from a set of questions that are at the heart of global climate policy debate. PEF addresses all facets of the climate issue that must be considered to answer these policy questions, using the best available scientific and socio-economic information. PEF is even flexible enough to address "what if" questions to explore different assumptions about aspects of climate change where limited information exists.

PEF has been used to investigate the relationships between the key uncertainties and the available policy alternatives. Nothing hinders the adaptability of the model to new information in science or economics. Further efforts will focus on refining the assumptions and scenarios used, especially in developing sectorally disaggregated impact functions.

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Disclaimer—The views expressed in this paper are the authors' own and do not represent official EPA policy.

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Rapporteur's Report

ANN HEIDENREICH*

Tuesday, 19 July 1994

Keynote Papers

Bert Bolin: Science, Values and Climate Change *[from my notes. I do not have a written paper]*

Developing response strategies to climate change requires dealing with two complex, chaotic systems, nature and human society, neither of which is predictable. Policy makers expect predictions on which to take action. Models can help us, but they cannot resolve our difficulties.

Models have a number of shortcomings. We cannot attribute climate changes experienced over the past 130 years to anthropogenic emissions. Models are global, and say little about local variations. No farmer is interested in the global picture. S/he is only interested in local variations. While the distribution of greenhouse gases in the atmosphere is homogeneous over the globe, climate forcing is not homogeneous. The presence of sulphate aerosols in the atmosphere reduces forcing in the North significantly. If we stop using fossil fuels, carbon dioxide will stay around for some 100 years, but sulphate aerosols will be gone within one month. What does this mean for different parts of the world?

Climate models do not contain all the physical and chemical elements. Emissions of CO_2 are the prime issue, but methane is also important. Methane has an indirect effect. Ozone may be present because of methane.

Economic models are assumed to be more predictable since they are built on assumed relationships of various parameters that cannot be related to human behaviour on the ground.

Given the inadequacies of models, we should not look at one, but a set of scenarios, to perceive the magnitude of risk. We need to go beyond the traditional economic view of what will happen and incorporate social aspects of society.

We do not know the answers to what Article 2 of the Framework Convention on Climate Change means. What are the levels of CO_2 that are tolerable from an ecosystem perspective?

Inertia of both natural and human systems requires early action. How dangerous is climate change? With the convention signed, we tend to bypass this question. We need to look at the potential impacts in order to know what are permissible levels of GHG emissions.

On the issue of equity, the impact of climate change will be very different in different countries. Sweden may profit while Bangladesh may not.

Graciela Chichilnisky: Meanings of Equity *[from transparencies and my notes]*

Why Socio-Economic Considerations?

The causes of climate change are economic, though the effects are physical and biological. Since the effects are physical, economists underestimate them. Even some of the best economists think that the effects of climate change will be so small that nothing should be done. Since the causes are economic, physical scientists cannot find solutions. Thus climate change requires thinking and acting across disciplines. This is difficult to achieve given the current organisation of the sciences.

Through climate change humans have turned the tables on nature. For the first time in recorded history, economic activity has reached dimensions at which it changes the atmosphere of the planet and its biodiversity. The most important climate risks today are induced by human action.

Why Equity?

Both the causes and the effects of climate change are closely linked with equity and inequity in the use of the global commons. The North's economy represents the main cause. The North has used, and continues to use, most of the global resources and environment: it produces 70% of all CO_2 emissions; it consumes most forest and mineral products; and it emits most CFCs. The South suffers most of the effects. It is most vulnerable to effects of climate change, especially on food production and on living conditions. The North produces most risks, and the South bears them most.

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Economic Development Based on the Satisfaction of Basic Needs and Sustainability

"Basic needs" were introduced (Chichilnisky, 1974, 1977) to rethink development patterns, so they would be consistent with environmental constraints. The concepts of basic needs and sustainability are contained in the Bariloche Model (1974–76), and taken up in the Bruntland Report.

Since climate change is global, it requires us to focus on global socio-economic issues and on global equity. However, economics is weak on equity issues. It is also weak on intergenerational concerns. Since economics is central to the climate negotiations, its weakness on equity issues is of concern.

Why is Economics Weak on Equity Issues?

The weakness on equity comes from focusing on markets with private goods, in which efficiency is divorced from distribution. The weakness in intergenerational justice comes from the use of discounted welfare criteria to maximise value across time. Discounting the future leads to undervaluing future environmental assets.

Markets are the dominant institutions in modern industrial economies. Markets are supposed to work efficiently independently of the distribution of income.

What is Economic Efficiency?

Total resources: $\Omega \in R^N, H$ people, each with a preference $u_h : R^N \to R$. An allocation $\Omega_1 \ldots \Omega_H \in R^{NxH}$ is feasible if $\sum \Omega_h = \Omega$.

A feasible allocation is Pareto efficient if there is no other feasible allocation which makes everybody (h = 1...H) as well off, and some strictly better off.

A market is $E = \{R^N, u_h: R^N \to R, \Omega_h \in R^N, h = 1,\ldots,H\}$ where $u_h : R^N \to R$ is the preferences and Ω_h the property rights of the hth trader on the N private goods.

A competitive equilibrium is a price $p^* \in R^N$ and an allocation $x_1, \ldots, x_H \in R^{NxH}$ such that each trader maximises utility subject to a budget constraint: Max $(u_h(y))$ for $y \in \{z \in R^N: \langle p^*, z\rangle = \langle p^*, \Omega_h\rangle\}$ and markets clear:

$$\sum_{h=1}^{H} x_h = \sum_{h=1}^{H} \Omega_h$$

First theorem of welfare economics: The allocation resulting from a competitive market equilibrium with private goods is Pareto efficient. This theorem is independent of the distribution of property rights

$$\Omega_1, \ldots, \Omega_H$$

For example: All but two traders may have zero endowments of property rights and the resulting equilibrium is still Pareto efficient. But it requires all traded goods to be private goods, with rival consumption, and privately owned.

Public goods change matters. A public good is a good which is not "rival" in consumption: This is not an economic or legal definition but rather a physical constraint. The allocation of the public good must be the same for all. Examples: the concentrations of CO_2 or CFCs in the atmosphere and the biodiversity of the planet. Environmental assets are generally public goods. CO_2 concentration in the atmosphere is not a typical public good because it is privately produced. A new economics is needed to deal with public goods.

A Competitive Market With Property Rights on Environmental Assets

An economy has H countries or traders who consume N private goods and one public good, a, the quality of the atmosphere. They trade private goods $x \in R^N$ and the rights to emit gases (CO_2) into the atmosphere. The more goods they produce the more energy they use, and the more carbon they emit, or the less they abate:

$$x = \phi(a_h) = \phi' < 0.$$

Countries (or traders) have property rights $\Omega_h \in R^N$ on private goods, and also property rights on the use of the atmosphere, such as total rights to emit, $a_h \in R$ [where a_h has a bar on the top], and preferences $u_h : R^{N+1} \to R$. They may use their rights to emit or trade these rights in the market.

Market Equilibrium with Emission Rights

Each trader chooses x_h and a_h to Max $(u_h(x_h, a))$ subject to $px_h = \phi$ $(a_h) = q$ (a_h [with a bar on top] $- a_h$); the value of consumption equals the value of production plus the permits they buy or sell, and all markets clear:

$$\sum a_h = \sum a_h \text{ [with a bar on top]} = a.$$

A competitive equilibrium is defined as before, but there is one additional physical constraint: The market allocation of the public good ($a_1, \ldots a_H$ [text goes off the page here] R^H must be the same for all $\forall h, h' : a_h = a'_h$.

Theorem 1 (Chichilnisky et al., 1993): There is only a finite number of ways of distributing property rights on environmental use between the traders so that the market equilibrium is Pareto efficient.

Policy: Those who have fewer endowments of private goods must be endowed with more property rights on the common environmental assets. Otherwise the market cannot operate efficiently. Efficiency and distribution are closely connected in economies with environmental assets. Equity is necessary for efficiency.

What about intergenerational justice? What about distribution between the present and the future? Can markets value properly environmental assets?

Axioms for sustainability: Chichilnisky, 1992 defines rigorously two formal axioms to evaluate welfare across generations: no dictatorship of the present; no dictatorship of the future.

The use of discount factors amounts to a dictatorship of the present. These axioms exclude discounted utility and all other welfare criteria used until now (overtaking criterion, Ramsey's criterion, long run averages, Rawlsian criterion). Yet there exist welfare criteria which satisfy both axioms, which I call sustainable preferences.

Theorem 2 (Chichilnisky, 1992): These two axioms fully characterise a welfare criterion of infinite streams of utility

$$\alpha = (u_1, \dots u_t, \dots) \in \ell_\infty:$$

$$W(\alpha) = \sum_{t=1}^{\infty} \delta(t) u_t + \phi(\alpha)$$

where $\phi(\alpha)$ is like the long run average and puts all the weight at infinity and $\Sigma_{t=1}^{\infty} \delta(t) < \infty$.

Theorem 3 (Chichilnisky, 1993): There exist intertemporal problems where the optimal solution according to a sustainable preference does not maximise the present value of intertemporal profits, for any discount factor.

Policy: Sustainable solutions may not maximise market value. Sustainability and markets define different value systems. Maximisation of present value is inappropriate as an intertemporal welfare criterion. Discounted cost benefit analysis is not adequate to evaluate long lived environmental projects. The presentation of long run stocks (forests, biodiversity, atmospheric quality) must be considered in addition to present value of the policy, and its physical feasibility must be evaluated with cross disciplinary methods.

In conclusion, the question "who is the future?" We must develop a sense of humanity as an organism which encompasses past-present-future, as global consciousness.

Hirofumi Uzawa: Equity in Economic Theory: Implications for Climate Change

[Hirofumi Uzawa wrote me a note saying he was sending the revised diskette of his paper to Dr Eric Haites. This is the abstract he gave me.]

Equity considerations loom large in the analysis of economic, social, and political implications of various policy and institutional measures for global environmental issues, particularly for global warming. The problems concerning equity in relation to global issues have two distinct features: intergenerational, on the one hand, and international, on the other. While the current generation benefits from the consumption of fossil fuels which contributes to an increase in the atmospheric concentration of carbon dioxide and other greenhouse gases, it is the future generations that have to suffer from the phenomena caused by atmospheric instability, such as global warming and other climate changes. By the same token, it is the developed countries which mostly benefit from those economic activities that cause atmospheric instability, while it is the developing countries which have to bear the burden of climate changes and other associated phenomena.

Traditional economic theory, however, has not given us a framework sufficienty broad enough to deal with the economic implications, from the equity point of view, of various phenomena of environmental disruption, particularly of global warming and the loss of biodiversity.

The concept of dynamic optimality, typically applied to assess the welfare implications of processes of economic development, entirely disregards the distributional aspects of the allocative process and exclusively focuses its attention upon the Pareto-optimality of intertemporal allocations of scarce resources. The system of optimum carbon taxes introduced to ensure the dynamic optimality of intertemporal processes of resource allocation necessarily implies that the identical rate has to be charged to the emission of carbon dioxide regardless of the country where it is emitted. Thus, if a carbon tax at the rate of $170 per ton, in the carbon content, of carbon dioxide emitted is charged in the United States, then the same rate of $170 has to be charged in Indonesia and the Philippines. The per capita assessment of the carbon tax then would be about $600 in the United States, where the per capita level of national income is $17,000, while it is about $170 in Indonesia where the per capita level of national income is $400, and, in the Philippines with the per capita level of national income $500, it is about $500, with disastrous implications for all economic, industrial and urban activities in Indonesia and the Philippines.

In contrast to the concept of dynamic optimality, the recently introduced concept of sustainability takes into consideration equity and distributional implications of processes of economic development, paying particular attention to the qualifying constraints that distributional equity is satisfied at each moment in time.

In the present paper, we should like to introduce those institutional measures, in the form of differentiated carbon taxes, which would guarantee that the ensuing processes of intertemporal resource allocation are sustainable and at the same time they are approximately dynamically optimum, meaning that the processes of intertemporal resource allocation approach the long-run stationary state of the atmospheric concentrations of carbon dioxide and other greenhouse gases which are optimum in terms of the intertemporal preference ordering prevailing in the society.

The basic analytical apparatus we will be applying in the present paper is that of the dynamic theory of optimum resource allocation, as originally introduced by Ramsey et al., and later extended by Mäler and Nordhaus to the situations where the environment plays a crucial role in the processes of economic development.

Comments:

Aubrey Meyer: In all presentations, one problem was not addressed. In the English language, equity has three meanings: (1) justice, which was dealt with in the last two presentations; (2) shares of money; and (3) collateral, that which underwrites the relationship between human beings. The biosphere is collateral for human society. All of these meanings need to "elide" with each other. ["elide" is what I think Aubrey said, but it doesn't make any sense to me.]

Yuri Izrael: Has there been an economic assessment of the positive effect of increased CO_2? In the history of the planet, has there been a time when CO_2 concentrations in the atmosphere were optimal? Are the present concentrations of CO_2 optimal for development?

Alex Alusa: Chichilnisky said that sustainability and markets define different value systems. Tradeable permits assume a market system that is perfect. What is Chichilnisky's view of tradeable permits in light of the present economic system?

Responses:

Graciela Chichilnisky: I am currently working on a programme to make the market for emissions permits compatible with equity issues. Rather than make a "Faustian" deal by selling emissions permits, we could think of borrowing/lending permits. This would require an institution—a bank for environmental settlements—that would organise the borrowing and lending of property rights on emissions. The bank would fix rates for optimal social and economic results.

Bert Bolin: There is no optimal concentration of CO_2 in the atmosphere. This is not a static but a dynamic question. We have established our habitats on the basis of the prevailing climate. The problem is the rate of change and the inability to adapt to rapid change.

Science, Society and Values

Steve Rayner: Roles of Science and Values in Climate Change Decisions *[see paper]*

Volker Linneweber: Evaluating the Use of Global Commons: Lessons from Research on Social Judgment *[see paper]*

Comment from Atiq Raman: Are we moving towards a world of greater or lesser equity?

Linneweber: To answer that question would be to concede that there is such a thing as "equity". There is no equity. Equity is a construction.

Rahman: Some of us think that the trading regimes proposed in the convention will enhance inequity. One has to be sure that some sort of progress is made with respect to equity.

Linneweber: Developing states are like children. They have to move through states of perceived inequity.

David Hallman/Ann Heidenreich: Religious and Socio-Cultural Concepts and Climate Change *[see paper]*

Comments:

Steve Rayner: Rayner said he resonates with some of the things said, but he wants to sound a note of caution about the romantic view of indigenous people living in harmony with nature/neighbours. This is clearly not the case. One should also be cautious against overgeneralising the role of consumerism in the North. This assumes that Northerners are mindless automatons. In both North and South, societies are extremely diverse.

Hallman responds: The risk of underrating indigenous knowledge is far greater than the risk of romanticising it. In fact, often consumers in the North do behave like automatons.

Comment [I don't know who said this] on the WCC critic of economics: Please do not throw the baby out with the bath water. If costs would be included in prices, then much of the problem would be solved.

Aubrey Meyer: In support of the WCC document, Meyer said he did not hear indigenous people being romanticised. On the question of consumerism in the North, Meyer said he went to a marketing conference recently where someone said: "The most successful corporation is the one that knows before its customers what its customers want." Meyer said, "We should not throw out the baby with the bathwater, but we should definitely throw out the bathwater."

Chichilnisky: The only way to advance economics is to recognise the shortcomings of the discipline. Oscar Wilde said: "An economist is one who knows the cost of everything and the value of nothing".

Tariq Banuri: We are at the end of the session on science, society and values. We have heard six people from the north talking about values, no one from Africa and Asia. Some things were left out. Values are intimately connected with institutions. Institutions in many parts of the world are weak and cannot defend values. Anger has been left out. We should not take what has been presented as the gamut from a to z.

Intergenerational Equity

Edith Brown Weiss: Intergenerational Equity and our Responsibility to Future Generations *[see paper]*

Prodipto Ghosh: Responsibility for the Actions of Past Generations *[see paper]*

Domenico Siniscalco and Andrea Beltratti: Economic Views on Intergenerational Equity

Discussants:

Chichilnisky: The issue of intergenerational equity moves us into the future. We have to take stock. What do we give to the future? What do we take from the future? We take resources—atmosphere, biodiversity, resources—these are the environment. What do we give to the future? Knowledge.

The concept of development has changed in the last 20 years. We used to think of development as resource intensive. Now we think of development as knowledge intensive. The degree of knowledge we have is our ability to have a good quality of life with minimal impact on the environment. There are two kinds of countries: (1) resource intensive, Africa is following a resource intensive pattern of development; (2) knowledge intensive, Asian economies. Knowledge is a public good. You can give it without losing it. Knowledge can lead to more cooperative solutions. Knowledge intensive development is not capital intensive. It is within the reach of poor countries. Some of the largest computer companies started in garages.

Why don't we jump ahead and adopt this model? The problem with knowledge is that it requires forms of organisation we don't have today. Current forms of property rights are not suited. They lead to a monopolistic system that is inefficient for supporting the public good.

Dipak Gyawali: Are we masters or custodians? You can be only one or the other. There is absolute need for an ethical base. There is no easy solution to the equity issue. In economics, there is an absolute belief in getting the price right. The other sciences have taken a back seat to economics since WWII.

It is important to question the assumptions behind neo-classical economics. A sales person once tried to sell an enormous frying pan to a village woman. The pan was so big it would not fit into her house. She asked, what is it for? He said, for frying eggs. She said, but eggs are not so big. He said, if elephants laid eggs... Economics is like the sales person. It is not in touch with reality.

The Third World has recently been joined by the Second World. This is the segment of the world that exports in order to import. The only country who has defied this is Japan, when it imports in order to export.

Foreign aid as an institution has collapsed. Development philosophy has collapsed. Now we have structural adjustment, which is fatalism. "You can't develop anyway. All we can do is manage you so you don't collapse". The transfer of wealth from South to North will have tremendous social consequences. It has already led to the collapse of the state as a resource. Currently, the state is an uneasy coalition of sub-national loyalties. Countries will be unable to implement the conventions. Investment in education is decreasing. The social limits to growth are already staring us in the face.

Aubrey Meyer: Six of nine presenters came from G-7 countries. The essence of the situation is simple. Equity for equity sake has failed. We are now in the situation where we have to have equity for survival's sake. That saves us or takes us all out. It's that simple.

Question: Is intergenerational equity easier to achieve than intra-generational equity? Is a concept of inter-generational equity politically more powerful than the concept of eco-system equity?

Michael Grubb: There are two types of discounting in economics: the way of classical economics and a second way (which I didn't get). If you accept the two axioms of Chichilnisky, you have to accept the welfare function.

Equity Considerations Among Countries

Chair : James P. Bruce
Richard S. Odingo
and Erik Haites

Rapporteur: J. Mani

Population and Climate Change

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Introduction

To most scientists—physical, biological and social—alike, the study of population and climate falls within the domain of human and physical geography respectively. This explains why traditionally geographers have perpetuated analysis of the phenomena, without being aided by other scientists who accuse geographers of meddling in their specialisations. With the emergence of formal demography and population studies, particularly after World War II, population and climate parted ways, the disciplines studying them becoming strangers with no concern for each other. The apparent cleavage has persisted and become more noticeable following the establishment of various specialised agencies within the United Nations system. Of relevance to this paper are the United Nations Population Fund (UNFPA) and the United Nations Environment Programme (UNEP) who are concerned with population and environment (including climate) respectively. Despite their relevance and usefulness to understanding and appreciating the place of the two phenomena, these United Nations agencies have worked and continue to work in isolation.

Evidence of the last point is manifested in previous events. World Population Conferences hitherto have never examined the relationship between population and climate change; similarly, UNEP has viewed climate without a demographic face.

This paper attempts to prove that there is a natural relationship between population and climate from two perspectives. The first and a more popular one, is that climate affects population or demographic behaviour. Although this perspective borders on "environmental determinism", it has preoccupied the attention of geographers, meteorologists and environmentalists, but who have rarely succeeded in ascertaining the nature and extent of the relationship. The second perspective relates to the influence of population/ demographic phenomena on climate. Two conceptual frameworks are proposed in the paper to enable readers to appreciate the nature and extent of the relationship between population and climate. These frameworks are amplified by citing relevant examples based on empirical evidence. By way of a conclusion, section four of the paper examines possibilities for a synergistic interpretation of population and climate change, two dynamic phenomena whose fluctuations are difficult to track. Longitudinal studies on fluctuations in climate and population, such as Galloway's (1986) in different parts of the world, point to the direction which climatologists and demographers should be following.

Effects of Climate Change on Population

The conceptual framework for analysing effects of climate change on population is shown in Fig. 1. Several climate variables affect population variables either directly or through several proximate variables.

In hostile environments with either hot, dry or cold, dry climates, the non-fluctuating conditions impact on population and human activity in general. Thus, the host deserts such as the Sahara as well as semi-arid areas repel population, resulting in very sparsely settled habitats. The cold deserts—the Siberia and much of the Tundra region has a similar effect. This latitudinal configuration and its inherent climate scenarios compares with altitude which also determines temperature which in turn affects population size, distribution and density. To this extent, Staszewski showed that "population numbers and densities diminish with altitude, a reflection of the increasing difficulties entailed in the exploitation of high geographic environments and adaptation to them". In low latitudes, altitude is advantageous to human settlement because it ameliorates climate, (Clarke, 1965, p.17). In the tropical world coastal areas and lake-shores provide a habitat that is conducive to mosquitoes which cause malaria, one of the world's deadliest diseases. It is not surprising that several strains of malaria are endemic in tropical areas where the disease causes high infant and childhood mortality as well as adult mortality.

Air and wind systems determine precipitation which results in either floods or drought which directly affect population, its settlement pattern and in some cases trigger morbidity and mortality as well as migration. The catastrophe associated with tropical cyclones, typhoons and monsoons is too commonplace to require further emphasis. Yet the damage done by these atmospheric turbulences on population and demographic behaviour is rarely analysed and meaningful policies prescribed to contain them.

Precipitation—its type, amount and pattern—also affects population and demographic behaviour in several respects. Hot, wet areas are good habitat for water-borne diseases which have become too thorny to eradicate. Populations have reacted by either out-migrating/emigrating or accepting morbidity and mortality as an aspect of their lifestyle. More importantly, precipitation determines water availability, vegetation cover and agricultural activity, all of which provide or negate human basic needs and give or deny sustenance to the population. The Sahelian part of Africa and many other such environments cannot contain large populations and even the available population is highly migratory in search of means for survival. Moreover, endemic drought and famine in those areas cripple human settlement and activity. The tropical forest zones in the other extreme provide the habitat for vector-borne diseases and pests which cause morbidity and mortality of the population whose only other alternative is out-migration/emigration.

Thus, climate change in itself does not necessarily affect population or demographic behaviour. Rather, it causes a chain of events which themselves influence the latter. It is these intermediaries that call more for critical examination.

Effects of Population on Climate Change

Over the last two decades a lively debate has centred on the impact of population or demographic phenomena (including human activity) on climate change (Fig. 2). Issues pertinent in this scenario are discussed briefly below.

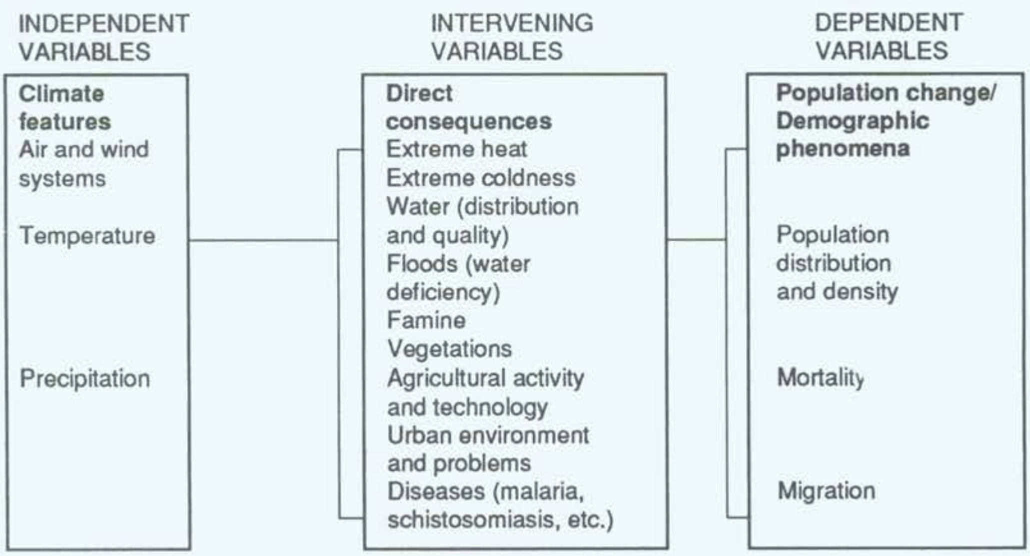


Fig. 1. A conceptual framework for studying effects of climate change on population.

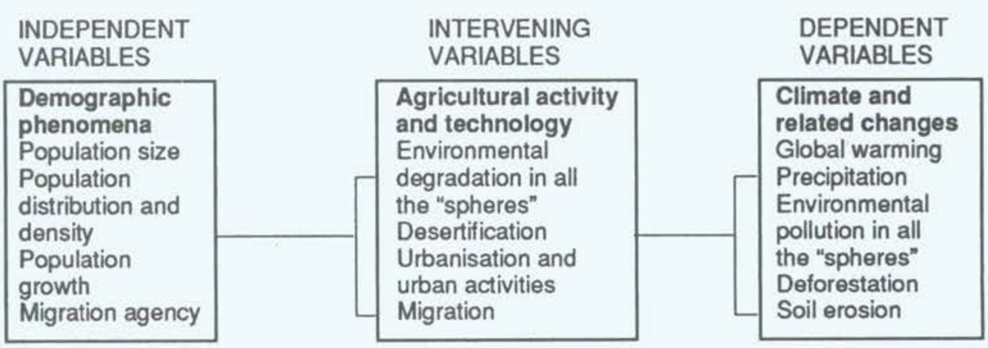


Fig. 2. Conceptual framework for studying effects of demographic phenomena on climate.

Global Warming

It has been asserted that population growth is responsible for about two-thirds of the increase in carbon dioxide (CO_2) emissions which increase the "greenhouse effect" that is largely responsible for the so-called "global warming" (United Nations Population Fund, 1991, p. 25). The point to stress is that human activity produces the five principal greenhouse gases—low-level ozone, chlorofluorocarbons (CFC), nitrous oxide, methane and carbon dioxide (CO_2) (p. 26). As these gases adversely affect natural resources, degrade land, pollute air and water bodies and devegetate the land, they set in motion other adversities (not least climate change) that affect human activity. In East Africa where population pressure on the land overloads the smallholder farming systems, the future of food production appears bleak and may collapse entirely (Stahl, 1993, p. 508). It should be remembered that in East Africa rainfall is positively correlated with agricultural activity and population density, the latter two often competing for the land. Thus, population size, distribution and growth tend to affect agricultural activity and technology first, before their impact is exerted on climate change and related changes.

Recent writings on global warming (Smil, 1990, 1991; Benedick et al., 1991; Bongaarts, 1992) cite examples which should provide bases for more systematic research in future. Bongaarts (1992, p. 301) endorses a chain of causation proposed by earlier studies (EPA, 1990; IPCC 1991) on global warming which shows that it is the *action of population* rather than population per se which causes global warming (Fig. 3).

Environmental Degradation and its Consequences

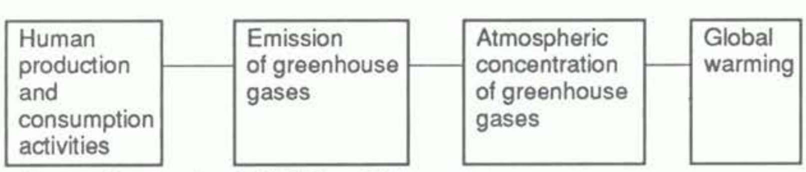
Both population size and population density can also lead to environmental degradation and a chain of other adversities. For instance, it may encourage agricultural practice and settlement patterns that cause soil erosion, desiccation of the environment or desertification. In some instances, migration has forced migrants to move into fragile arid or semi-arid environments where they have aggravated environmental degradation. Also, land colonisation by peasant farmers tends to encourage deforestation and a drastic change in the hydrological cycle, changing the climatic regime for the worse.

As in the first conceptual model, the second model suggests that population or demographic phenomena does/do not act alone to influence climate and related changes. They operate through various proximate variables to affect the latter.

Conclusion

This brief presentation has underscored the need to examine the relationship between population and climate in a manner that each of the two constitutes a dependent variable. From the two models presented and some empirical evidence provided, it is clear that multidisciplinary approach is obligatory in an attempt to decompose independent, intervening and dependent variables at play. The IPCC could have its work enriched by involving demographers and population geographers in exercises hitherto undertaken principally by physical and biological scientists, joined only by physical geographers. Indeed, the whole arena of environment of which population and climate are but components, stands to benefit greatly from the inclusion of the two, and more. As all roads begin to converge towards the International Conference on Population and Development (ICPD) due in Cairo, Egypt in September 1994, the IPCC and the UNFPA should of necessity forge links to map out future strategies for a comprehensive population-sensitive climate convention.

Miller's (1994) interpretation of global change across the social and natural sciences should provide useful lessons for interactive and collaborative analysis of population and climate. Even if no formal collaboration evolves between scientists representing the two scientific stances, she observes, there should be cooperative but parallel multidisciplinary research (p. 21). In this connection, the conceptual model relating various systems (political systems and institutions, population and social structure, global scale environmental processes, preferences and expectations, factors of production including technology and economic systems) within the framework of the Human Dimensions of Global Environment Change Programme (HDP), is instructive (Miller, 1994, p. 23). The HDP Working Group has shown the importance of population



Source: Bongaarts, J. (1992), p. 301.

Fig. 3. A chain of causation of global warming.

and climate data in interpreting the general circulation models (Clarke and Rhind, n.d.). The ideal situation should be more collaboration between the IPCC and HDP as well as the International Union for the Scientific Study of Population (IUSSP) whose scientific mandates are likely to shed light on population-climate relationship.

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Environmental Refugees and Climate Change: Estimating the Scope of What Could Well Become a Prominent International Phenomenon*

NORMAN MYERS+

The gravest effects of climate change may be those on human migration as millions are uprooted by shoreline erosion, coastal flooding and agricultural disruption.

—Intergovernmental Panel on Climate Change (1990a)

We increasingly hear about environmental refugees. They are people who can no longer gain a secure livelihood in their erstwhile homelands because of drought, soil erosion, desertification, and other environmental problems. In their desperation, they feel they have no alternative but to seek sanctuary elsewhere, however hazardous the attempt. Not all of them have fled their countries; many are internally displaced. But all have abandoned their homelands on a semi-permanent if not permanent basis, having little hope of a foreseeable return (Myers, 1986, 1993; see also Barker, 1989; El-Hinnawi, 1985; IOMRPG, 1992; Jacobson, 1988; UNPF, 1993).

It is often difficult to differentiate between refugees driven by environmental factors and those driven by economic problems. In certain instances, cross-border refugees, notably those with moderate though tolerable economic circumstances, are pulled by opportunity for a better economic life elsewhere rather than pushed by environmental destitution. This description obstensibly applies to many Hispanics heading for the United States. But those people who migrate because they suffer poverty are frequently driven by root factors of environmental degradation; indeed, it is their environmental plight as much as any other factor that makes them economically impoverished. This description generally applies to those refugees who migrate to another part of their own country or head off to a neighbouring country where economic conditions are a little if any better than back home, as is in the case of many migrants within sub-Saharan Africa and the Indian Subcontinent. In this instance, with poverty and life on the environmental limits as the main motivating force, it matters little whether the migrants are labelled environmental or economic refugees.

According to recent estimates (Trolldalen et al., 1992; Westing, 1992), there are at least 10 million environmental refugees today (roughly half of them in sub-Saharan Africa), compared with 17 million other refugees (e.g., political, religious and ethnic) combined. The first figure is certainly on the low side, because governments generally take little official account of this unconventional category of refugees; it is the unrecognised refugees that have shown most increase in recent years until they may now number (roughly estimated) as many as 25 million. Even if we accept a total of only 10 million recognised environmental refugees today, cautious and conservative as the figure is, we can assume that their numbers are likely to swell rapidly as burgeoning throngs of impoverished people press ever harder on overloaded environments (Ehrlich and Ehrlich, 1990, 1991; Myers, 1991, 1992a). Worse, their numbers may well increase several if not many times by the time that global warming takes hold (Myers, 1993).

What evidence is there to support the latter prognosis for a greenhouse affected world? This article presents a preliminary analysis to gain a first-cut understanding of the problem in its full character and extent. Some of the analysis is speculative, and in certain instances there is a range of estimates. Plenty has been written about the impacts of global warming, but little attention has been directed to the emergent issue of environmental refugees, and hardly any detailed work has been done to assess the prospect in comprehensive and systematic terms

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(for introductory efforts, see Jacobson, 1988; Tickell, 1990). To the extent that there is substance to a prediction of large numbers of environmental refugees ahead, it serves as a powerful further rationale for policy measures to slow global warming while there is still time. This article is intended to stimulate debate and further assessment. To reiterate, the analysis presented is essentially exploratory—no more and no less. It seeks to establish the scale and scope of what could well become a prominent phenomenon of the international arena.

A note on the analytic methodology: The article uses the baseline or business-as-usual (little or no control of greenhouse gas emissions) scenario for global warming and sea-level rise, with uncertainty ranges (where available and appropriate) as presented by the Intergovernmental Panel on Climate Change (IPCC, 1990a, 1992a). The marker year used for the articles assessment is 2050, when global warming impacts are likely to have become widespread and pronounced. It is expected there will be a sea-level rise worldwide of approximately 8–29 cm (with a most likely increase of 18 cm) by 2030, and of 25–110 cm (the best estimate being 46 cm, or approximately half a metre) by 2100 (Warrick, 1993; Warrick et al., 1993; see also IPCC, 1990a, 1992a); a working estimate for 2050 is 30 cm and that is the value used in this article. By 2050, according to a medium projection, global population is expected to have almost doubled to 10 billion people, virtually all the increase being in developing countries (United Nations, 1992; World Bank, 1992a). Moreover, the entire analysis is limited to developing countries, because these areas have the largest populations at risk and because they possess fewest resources (engineering skills, financial means, and institutional capacity) to confront the problem.

Finally, the analysis assumes there will be few protection measures adopted in the form of, for example, sea-wall defenses. True, much could be done to reduce the threat through sea walls, anti-flood levees and dikes, upstream dams, beach nourishment, and other engineering defenses, plus land-use planning to deflect human settlements away from at-risk zones (IPCC, 1992b; Titus, 1990, 1993; Titus et al., 1991; USNRC, 1987). But the costs of such measures are likely to prove unduly high for many developing countries. Let us now consider some individual countries and regions as they undergo the potential impacts of global warming.

Bangladesh

The April 1991 cyclone that struck the country's coastal zone and the accompanying six-metre-high storm surge that penetrated far inland caused the loss of at least 200,000 people (some observers estimate twice as many), and millions were left homeless—all in a single sector of one small country (del Mundo, 1992; Haider, 1992). Bangladesh is the size of Florida or England, with 114 million people in mid-1993 and the highest population density nationwide on Earth. The Netherlands, the most crowded nation in the developed world, has an overall density only half as high. Moreover, approximately 85% of Bangladeshis live in rural areas, so the whole national territory is congested with people, compared with say the Netherlands, where only 11% of the populace live in the countryside.

In addition, more than half of Bangladesh lies less than 5 m above sea level, leaving it more vulnerable than most other countries to sea-level rise (Broadus, 1993; Nicholls and Leatherman, in press a, b). Because of the twin factors of population density and low-lying terrain, Bangladesh is unusually susceptible to extreme events, such as cyclones, together with associated phenomena of storm surges and coastal flooding (Flather and Khandker, 1993). In recent years, the country has been struck by cyclonic storms at an average rate of 1.5 per year (Broadus, 1993; see also Topping et al., 1991). Moreover, global warming may well produce an intensification of the cyclone system, leading to outsize variations of storm surges (Emanuel, 1988; Pittock and Flather, 1993; Raper, 1993).

Bangladesh is also highly susceptible to flooding inland, again because of its low-lying territory. The country straddles the floodplains confluence of three great rivers: the Ganges, Brahmaputra, and Meghna. In effect, 80% of the country is one great delta, where even a slight increase in water level leads to widespread flooding (Brammer, 1993; Broadus, 1993). Half of the Gross Domestic Product (GDP) is attributable to agriculture (in many developing countries the proportion is one third or less), leaving the national economy all the more prone to flooding damage (Broadus, 1993; World Bank, 1989).

Consider a sea-level rise scenario for Bangladesh, based largely on the most detailed analysis to date, viz Broadus 1993 (See also Ali and Huq, 1990; Mahmood, 1991; Mahtab, 1989; Milliman et al., 1989; Pramanik and Ali, 1989). A May 1985 storm surge raised sea level in the northeastern sector of the Bay of Bengal by 2.75 m (Flather and Khandker, 1993). The impact of sea-level rise will be augmented by land subsidence, both natural and human caused (the latter mainly through withdrawal of ground water), virtually throughout Bangladesh's coastal zone (Broadus, 1993; Milliman et al., 1989). It is possible that subsidence, if it continues as anticipated due to increased human exploitation of coastal zone resources (also through damming of rivers upstream, thus reducing sediment flow to estuaries from catchment zones), will exceed the maximal projected sea-level rise by the year 2100 (Turner et al., 1990).

These factors combined could well cause an effective sea-level rise of 0.83 m along Bangladesh's coastline by 2050, comprising 0.13 m through sea-level rise and 0.70 m through subsidence. The analysis cited (Broadus, 1993) considers that this rise can be viewed as more or less equivalent to an effective one-metre rise for the purpose of scenario assessment. In conjunction with associated problems, such as storm surges and tidal waves, Broadus calculates a one-metre sea-level rise would precipitate severely adverse impacts for Bangladesh's coastal zone and immediate hinterland. (The analysis leaves out of the account the further impacts on inland areas up to five metres above sea level, which comprise more than half the country). The analytic methodology is described by Broadus as "very simplistic," the projections as "highly speculative," and the conclusions as "a very coarse approximation" of economic repercussions. The analysis by Broadus does not include possible measures to reduce the problem.

Although Broadus contends that a one-metre scenario is to be viewed in certain respects as a worst-case outcome, he proposes that a three-metre scenario for 2100 is worth consideration. In light of the bleak outlook for Bangladesh, however, the analysis certainly deserves the attention of political leaders and policy makers. Note, too, that by 2050, Bangladesh is projected to have approximately 220 million people, or almost twice as many as today (United Nations, 1992; World Bank, 1992a).

The outcome could prove critical for a country that, with a current per capita gross national product (GNP) of $ 200, ranks among the most impoverished on the Earth, meaning that it can deploy few resources—financial and engineering, for example—to resist natural disasters. Seven percent of Bangladesh could permanently disappear beneath the waves, and a much larger area could be regularly overtaken by associated phenomena such as six-metre storm surges reaching 160 km or more inland (World Bank, 1989), that is, two-fifths of the way from the coast to the main northern border. In April 1991, it was not so much the cyclone that killed 200,000 or more people, rather it was the in-rush of seawater that drowned them.

Taken together, by 2050 the expected hazards would destroy homes and holdings in an area containing 7% of today's populace (Broadus, 1993; see also Mahtab, 1991; Milliman, et al., 1989). If population distribution continues as today, the number of people affected in 2050 would be a projected 15 million. Even if the catastrophe could be partially contained through massive engineering works (long-term costs are estimated as high as $ 10 billion for a country with a present day GNP of $ 24 billion; Huq et al., in press), there would be further problems from ripple effects in the form of backwater flooding in inland areas and acute congestion in the new coastal zones (Topping, 1990). Moreover, the victims could look for little help from a currently destitute nation that would lose a sizeable share of its economic base.

On top of all these problems stemming from the encroaching sea, there could be trouble for Bangladesh from the opposite side of the country, the Himalayas. The three great rivers pouring into Bangladesh carry exceptionally swollen waters after the monsoon strikes the Himalayas. Their combined outflow is two and a half times that of the Mississippi and surpassed only by that of the Amazon (Topping, 1990; see also Brammer, 1993). Less than one tenth of these rivers' catchments lies within Bangladesh, leaving the country with next to no control over the vast volumes of water pouring into its territory.

In September 1988, river flooding left three-quarters of the country inundated, with 50 million people rendered homeless and $ 1.5 billion worth of damage (equivalent to 6.5% of GDP or a whole year's economic growth; World Bank, 1989); the disaster had nothing to do with waters from the sea. If global warming causes the monsoon system to have a more powerful impact, the rivers' flow into Bangladesh could expand by at least half during the monsoon season (Rasmusson, 1989). There would also be increased melting of the Himalayan glaciers. Indeed, some experts believe the threat from inland flooding may turn out to be more serious than the better-recognised threat from rising sea level (IPCC, 1990a, 1992a).

There is yet another problem: Increased salt-water intrusions. Already these intrusions can extend seasonally 150 km inland along river courses (Broadus, 1993). A relative sea-level rise of one metre would cause such intrusions to reach even further inland, with adverse repercussions for irrigated cultivation of rice and other crops, and for household water supplies.

The main analysis reviewed (Broadus, 1993), based largely on effective sea-level rise, is to be deemed a severe outcome scenario. But a number of additional adverse factors would make it plausible if not probable in many respects.

Egypt

The River Nile supports a 10 km wide strip of farmlands plus the delta plain, totalling 35,000 square kilometres or a mere 3.5% of the nation's territory. In this area live 57 million people today, making for a local population density of approximately 1600 per square kilometre, or more than twice the nationwide density of Bangladesh. Already Egypt has difficulty feeding itself, having to import well over half its food (World Bank, 1992b). But in a greenhouse affected world, it may well be that drier conditions will cause a one-fifth drop in the corn yield and a one-third drop in the wheat yield—a prospect that would be aggravated by a marked decline in the Nile River flow (Gleick, 1991). Food shortages are likely to be exacerbated still further by sea-level rise through permanent flooding of prime agricultural lands. Moreover, the area worst affected by sea-level rise, the Nile delta, is experiencing rapid natural subsidence (Stanley, 1990), aggravated by sediment starvation due to the Aswan High Dam upstream.

According to the latest detailed analysis, again by Broadus (1993; and subject to the caveats he stipulates for his Bangladesh analysis), Egypt could plausibly experience 0.13 m of global sea-level rise and 0.65 m of local subsidence by 2050 (though Stanley [1990] postulates only 0.20 m of subsidence), making a total of 0.78 m of effective sea-level rise. As in the case of Bangladesh, this latter figure is rounded up by Broadus to 1 m. A relative one-metre sea-level rise would permanently flood much of Egypt's delta plain for 30 km inland (El-Raey et al., in press; Milliman et al., 1989). The country could well lose between 12 and 15% of its arable land, containing 14% of the current population of 8 million people. Given that Egypt's population is projected to increase to 103 million by the year 2050, and supposing that population distribution remains the same as today, it is realistic to anticipate that sea-level rise would displace more than 14 million people by 2050 (Broadus, 1993).

This prognosis, moreover, is cautious and conservative. There would be additional problems, such as intrusion of salt-water up the foreshortened Nile (Kashef, 1983), that would further reduce the irrigated lands supporting virtually the whole of Egypt's agriculture. On the other hand, if the elevation of the coastal city Alexandria, with 4 million people today and projected to contain 8 million by 2030, were to prevent it from being flooded out (expensive engineering works would still be required to counter sea-level rise; El-Raey et al., in press; Perdomo and Vellinga, 1992), then only 7% of the population would be displaced (Broadus, 1993).

Other Delta Areas and Coastal Lands

All in all, as much as five million square kilometres of coastal lands could be threatened by a one-metre sea-level rise plus storm surges and salt-water intrusions (Hekstra, 1990; UNEP, 1989).. This aggregate area is equivalent to the United States west of the Mississippi, but amounts to only 3% of Earth's land surface. Yet, it is home to well over one billion people already, a total projected to rise to at least two billion well before 2050 (it also encompasses one third of the world's croplands and one fifth of the market-valued assets; Voigt, 1991; see also Wilson, 1989). As early as the year 2000, the majority of humankind could be living within 60 km of coastlines (Voigt, 1991). As we have seen, cyclone flooding in Bangladesh can extend 160 km inland, though fortunately few coastal zones are as low lying as Bangladesh's.

True, we are unlikely to witness a one-metre rise in sea level even by 2100, or more than 0.33-metre rise by 2050, according to the latest working estimates (Warrick, 1993; Warrick et al., 1993). Only a small proportion of the coastal-zone communities would be affected. But the number of displaced people would be significant, although currently difficult to predict except in very general terms.

In addition to Bangladesh and Egypt, the countries at greatest risk by virtue of their low-lying coastal plains with large populations are China and India, together with several other countries facing a lesser though still sizeable risk—Indonesia, Thailand, Pakistan, Mozambique, Gambia, Senegal, and Suriname (Nicholls and Leatherman, in press a, b; see also Jacobson, 1990; Titus, 1990; Topping, 1990). A country does not have to feature a broad and shallow coastal plain to qualify for the list. Indonesia's coastal zone generally gives way quickly to uplands, yet its 13,000 islands comprise coastlines totalling 81,000 km (Sughandy 1989; compare the United States' 20,000 km and the world's 450,000 km). Nor is the problem limited to sea-level rise. Coastal zones can be severely affected by storm surges. Already some 100–200 million people live below the annual storm surge level (Perdomo and Vellinga, 1992).

China

China's coastal zone of 126,000 square kilometres, an area equivalent to New York state, contains 76 million people today. It also features industrial and agricultural activity worth one quarter of the country's GDP (Perdomo and Vellinga, 1992). Its population density is higher than that of Bangladesh's nationwide, yet the elevation in the coastal strip is only 1 m (Han et al., 1990; Wang et al., 1992). The zone is also characterised by local subsidence; Shanghai has sunk 2.8 m since the 1920s and may subside a further 1 m by 2100 (Wang et al., in press; see also Hsia-Chuang, 1991). An effective one-metre sea-level rise, made up of subsidence in conjunction with actual sea-level rise, would inundate the whole of Shanghai with its 12.4 million people today, projected to increase to 26.8 million by 2030. Flooding would also overtake

96% of the surrounding province, reducing the area available to move the city inland through slow relocation of new buildings (Wang et al., in press).

Even a half-metre sea-level rise would, according to Chinese government estimates (Ruquiu, 1990), eliminate the homes of 30 million people today (a minimum of 29–34 million people are at risk in the four major deltas alone; Han et al., in press). The government further estimates that as many as 100 million people would ultimately be affected to some degree by coastal flooding, albeit without being obliged to migrate. Nor would there be much room for migrants merely to move a little way inland. In the coastal plain as a whole live 350 million people already, with a congestion quotient as high as for rural areas anywhere on earth. Although there is no estimate for the coastal-plain population in 2050, we can note that the population for all of China is projected to increase from 1179 million today to 1764 million by 2050, a 50% increase (United Nations, 1992). If the same proportionate increase were applied to the coastal-zone sector, the figure of 350 million people today would rise to 525 million in 2050.

It seems realistic to accept the government's estimate that 30 million people would be displaced, a highly conservative estimate. In an alternative calculation (Cline, 1992), 72 million people are displaced.

India

In the country's sector of the Bay of Bengal, comprising West Bengal and Orissa states adjacent to Bangladesh, there would be less than 2000 square kilometres and only approximately 1 million people at risk, contrasted with the total of 15 million people estimated for Bangladesh in 2050. The main problem would lie with some large deltas in several other sectors of India's coastline (Perdomo and Vellinga, 1992), five of which cover more than 21,000 square kilometres and support more than 21 million people today (Nicholls and Leatherman, in press a, b). India's total coastal-zone population today is 180 million people, of whom almost 80 million together with 120,000 square kilometres of land, would ultimately be affected by sea-level rise, though not all would necessarily be displaced (Asthana, in press). India's population of 899 million people today is projected to rise to 1599 million by 2050, a 78% increase. If we apply a similar percentage increase to the 80 million coastal-zone dwellers today, the total for 2050 would become 142 million.

Using this background data, because no better estimate is available at present, it seems appropriate to propose that India's total of flood-zone refugees alone could be anywhere between 20 million and 60 million, with 30 million taken here as a conservative working figure. This estimate is among the roughest advanced in this article. It is adopted on the grounds that the total must be in the low tens of millions. The estimate could turn out to be too cautious by several tens of millions.

Return to the aggregate area cited for all coastal lands at risk, totalling 5 million square kilometres. The expanse includes those sectors of Bangladesh and Egypt already considered, with a combined total of approximately 30 million potential refugees. Let us suppose that all other areas together, including China and India (30 million each), would generate another 70 million refugees, the additional 10 million refugees occurring in further coastal lands. Plainly, this estimate is rough indeed: It is advanced only with the purpose of enabling us to get to preliminary grips with an issue of major moment. Equally plainly, the figure is conservative.

We can adduce evidence in support of the figure of the 10 million refugees from other coastal lands by considering a number of other deltas, together with estuaries that would be vulnerable to even a moderate degree of sea-level rise. Among such areas are the mouths of the Hwang ho and Yangtze rivers in China, the Mekong in Vietnam, the Chao Phraya in Thailand, the Salween and Irrawaddy in Myanmar, the Indus in Pakistan, the Tigris/Euphrates in Iraq, the Zambezi in Mozambique, the Niger in Nigeria, the Gambia in Gambia, the Senegal in Senegal, the Magdalena in Colombia, the Orinoco in Venezuela, the Courantyne and Mazuruni in British Guiana, the Amazon and Sao Francisco in Brazil, and the La Plata in Argentina, plus less extensive areas at the mouths of other major rivers (Delft Hydraulics, 1990; Frassetto, 1991; Topping, 1992). Yet, these low lying areas feature some of the densest human settlements in the world. In the Mekong delta, for instance, 10 million people now live in areas with elevation no more than 1 m above high tide (Hekstra, 1990).

Low lying deltas and estuaries feature the megametropoles of Shanghai, Manila, Jakarta, Bangkok, Calcutta, Madras, Bombay, Karachi, Lagos, Rio de Janeiro, and Buenos Aires (Frasseto, 1991; Perdomo and Vellinga, 1992). Their collective populations amounted to 93 million in 1985 and are projected to reach 141 million people as soon as 2000 and as many as 200 to 220 million (for total conurbations) by 2050 (UNPD, 1993). Some urban areas are subject to subsidence (Dolan and Goodell, 1986). Because of groundwater pumping, Bangkok's subsidence rate is 13 cm a year (Milliman et al., 1989), a rate that if continued will amount to 1 m in only 8 years. Subsidence may well increase in many other urban areas as groundwater stocks are increasingly exploited for agriculture, industry, and household needs. In the case of several of these outsize cities, subsidence is expected to contribute to an effective sea-level rise of 1 m if not more by 2050 (Dolan and Goodell, 1986; Topping, 1992).

Suppose that only one-eighth of the projected populations of developing nations cities listed, 210 million in all, were to become displaced by sea-level rise and related troubles such as storm surges and tidal waves. (Although this calculation is again crude, it is based on an early assessment by the United Nations Environment Programme [1989], which postulated a higher proportion, one quarter; the proportion has been reduced to one eighth for current purposes to reflect the reduced amount of sea-level rise now anticipated for 2050, roughly half a metre rather than one metre [Warrick et al., 1993]). So the one-eighth calculation would generate 26 million environmental refugees. Of the 11 cities listed, Shanghai, Calcutta, Madras, and Bombay have already been accounted for through the analyses of China and India above. Their collective populations in 1985 were 38 million, or 41% of the 11-city total of 93 million (Sadik, 1991). If we apply the same percentage figure to the 11-city total population of 210 million for 2050, it will amount to 86 million, leaving 124 million for the other 7 cities. It is not unrealistic to suppose that this latter total should generate 26 million environmental refugees.

Note that the 26 million figure is distinctly conservative from a broader standpoint. The megametropoles considered are located on only 6 of the 19 delta/estuary areas listed. Several of the 13 other areas feature sizeable urban communities though not so large as the 11 conurbations considered. Moreover, the refugee total would be higher yet again if we were to include smaller cities (plus smaller delta areas and estuaries). Already, two out of three cities with 2.5 million people are located on coasts (Voigt, 1991). This analysis serves to affirm as realistic the estimate of 10 million further refugees in additional coastal lands.

Island States

Also at risk are a number of island states such as the Maldives, Kiribati, Tuvalu, and the Marshalls in the Indian and Pacific Oceans, plus a dozen or more such states in the Caribbean. The first group will be acutely vulnerable to sea-level rise and flooding insofar as virtually their entire territories lie only a metre or two above sea level; several of these islands face the prospect of outright elimination. The collective population of the non-Caribbean islands states is 24 million today (Topping, 1992), projected to surpass 50 million by 2030. Fortunately, only 1 million people at most are likely to find themselves having to evacuate permanently, though as many as 46 million of the 50 million people can find their homes and livelihoods critically affected (Jacobson, 1988).

The Caribbean island states may eventually become subject to tropical storms of increased intensity over a longer season. These storms may be sufficient to reduce greatly the suitability of parts of the islands for permanent human habitation.

Agricultural Dislocations

On top of the problems associated with sea-level rise is the prospect of other global warming effects, such as shifts in monsoon systems and the arrival of severe and persistent droughts, with all that they would entail for agriculture. A temperature rise of only 1°C, likely by 2050 in terms of most projections, could affect monsoon patterns to an extent that would dwarf the direct drought effects of such a temperature rise (IPCC, 1990a). The area most vulnerable to monsoon dislocations is the Indian subcontinent, projected to hold 2.1 billion people by 2050. India relies on the monsoon for 70% of its rainfall (Rasmusson, 1989); hence, its agriculture is critically dependent on the stable functioning of the monsoon. In broader terms, the entire Asia-Pacific region is exceptionally vulnerable to monsoon system changes, if only because it contains well over half the world's population today, projected to become a still larger proportion by 2050 (Topping et al., 1991).

Predicting the effects of drought and its repercussions for agriculture is more uncertain. Climatic quirks are less well predicted through global-climate models at regional levels than are monsoon patterns, sea-level rise, and cyclone systems. Areas considered susceptible to drought include much of northern Mexico, northern Chile, northeastern Brazil, eastern Argentina, the Mediterranean basin, the Sahel, the southern quarter of Africa, and sectors of the middle and tropical latitudes of Asia, as well as parts of the United States, southern Canada, southern Europe and Australia (Schneider, 1989). The latter four areas produce much of the surplus food that sustains more than 100 developing countries today.

According to some recent innovative analysis (Daily and Ehrlich, 1990) involving drought among a host of other agricultural problems, a plausible global-warming scenario for early next century indicates there could be a 10% reduction in the world grain harvest on average three times a decade. The 1988 droughts in just three of the major grain-producing countries, the United States, Canada, and China, resulted in an almost 5% decline; and a mere 0.5°C increase in temperature could reduce India's wheat crop by 10%.

Given the way the world's grain reserves have dwindled almost to nothing as a result of the late 1980s droughts (Brown et al., 1992, 1993), it is not unrealistic to reckon that each such grain-harvest shortfall would result in huge numbers of starvation deaths—according to the computer-model calculations, from 50 million to 400 million people (Daily and Ehrlich, 1990). Megascale famines are held at bay today in part through food shipments from the great grain belt of North America, among other food-exporting regions. In a greenhouse-affected world, this grain belt could become unbuckled to the extent that there would be fewer such shipments as Americans find it harder to feed themselves, let alone other communities.

This analysis has been reinforced by a still more recent and much more detailed assessment (Rosenzweig et al., 1993). This assessment postulates that global warming will reduce cereal production in developing countries by 9–11% by the year 2060. In conjunction with other factors, such as population growth and increased food prices to reflect scarcity, this reduction could cause a projected expansion of 640 million in the number of hungry people bringing the unfamished total to 1 billion. The date of 2060 used by Rosenzweig extends the analysis a little further into the future than the marker date I am using, 2050. But food shortfalls are expected to start to occur within just a few decades.

Particularly vulnerable would be Africa, where regions at special risk of enduring drought include North Africa, West Africa, the Horn of Africa, and southern Africa (IPCC, 1990b). The region's population today is 674 million, projected to reach 2.1 billion by 2050 (a 3.2 times increase; United Nations, 1992; World Bank, 1992a).

The principle agricultural problem is expected to be lack of soil moisture during the growing seasons. In North Africa, for instance, evapotranspiration would increase by 10% for each temperature increase of 1.5°C. Even without any change in rainfall (it is expected to decline), this evapotranspiration would deplete river flows by more than 10%, causing irrigable croplands to contract (IPCC, 1990b; see also Russell et al., 1990; Suliman, 1990). In sub-Saharan Africa alone, there is already a food deficit of 12 million tons, predicted to increase to 50 million tons by 2000 and 250 million tons by 2020; the amount of relief food shipped throughout the world today is 12 million tons (Pinstrup-Andersen, 1993). Even an optimistic scenario for Africa (e.g., reduced population growth, enhanced soil and water conservation, and expanded irrigation; Kendall and Pimentel, in press) foresees that per capita grain production in 2050 would be well below today's sorely inadequate level. Hence, Africa would be ultra-vulnerable to even minor climate disruptions.

Starvation crises of unprecedented scale would surely trigger mass migrations of people from famine-afflicted areas. How many is difficult to say with even a modicum of precision. But for the sake of getting a handle on what could become one of the most significant phenomena of the coming decades, it is reasonable to hazard an informed estimate of 50 million refugees—possibly, or probably, many more. One recent estimate (Suliman, 1990; see also Russell et al., 1990; Tamondong-Helin and Hellin, 1991) postulates 50 million in Africa alone.

Further Conceptual Dimensions

These estimates of future numbers of environmental refugees are a case of best judgment. They are intended to be exploratory at most. A few of them could be off target by 10 million or even more either way, though more probably on the low side insofar as the analyses are conservative. And even if the overall total were too high by one third, or 50 million people, this refugee problem would still be of altogether unprecedented scale.

The totals could also be affected by questions of classification. Although many people will be threatened by environmental factors in a greenhouse-affected world, will they necessarily be obliged to migrate? Or should they better be viewed for the time being as only at risk, especially insofar as ameliorative measures may be deployed to safeguard them? If they do move, what constitutes true migration? Some people displaced by sea-level rise may need to move their place of residence only a short distance; certain coastal communities may find that residents need simply move across town, albeit a town that may itself be having to move inland with all the further societal traumas that would entail.

Moreover, several of the megametropolises listed may already be experiencing severe problems due to a 50% or greater increase in population size in their recent past (United Nations, 1992). This ultrarapid growth may have already overwhelmed the cities' capacity to cope generally, let alone to confront the particular problems of coastal flooding. Equally to the point, people seeking to escape from coastal flooding by moving across town may find there is little room to accommodate them in already congested and overloaded areas; or they may serve in turn to displace sectors of resident communities. There could be all manner of ripple effects.

Many other environmental problems will have overtaken large numbers of people well before

2050 and thus predispose sizeable communities to move elsewhere as soon as the further problems of global warming arrive. For instance, severe water shortages are expected to affect 1.1 billion people in Africa, and 3 billion people worldwide, as early as 2015 (Falkenmark and Widstrand, 1992), providing a potent source of further refugees. Other environmental problems with a capacity to generate refugees are tropical deforestation (for details of the potential refugees connection, see Ehrlich and Ehrlich, 1990; Myers, 1992b), and the soil erosion and desertification among other forms of land degradation (Myers, 1991; Pimentel, 1993). These changes will be taking place in countries likely to have experienced doubling and in some cases tripling of their populations by 2050, grossly reducing their capacity to accommodate to environmental problems (Ehrlich and Ehrlich, 1990; Myers, 1991, 1992a; UNEP, 1989; Odum, 1993).

More important still, global-warming stresses may exert not just an additive effect. They may interact with other environmental stresses in multiplicative fashion, that is, with compounded impact. When such synergistic interactions occur, they generate not a double problem but a super-problem, sometimes with ten times greater impact than the sum of their individual impacts (Jackson and Black, 1993; Odum, 1993).

For instance, in a greenhouse-affected world many agricultural regions look likely to experience higher temperatures and reduced soil moisture, notably the drought-prone sectors of Africa listed above; yet, most of our agricultural crops are finely tuned to present climate conditions. Hence, there will be need to expand the genetic underpinnings of our crops—a need that will place a premium on germplasm variability to build up, for example, drought resistance. The same need applies to genetic adaptations for crop plants to counter new pests and diseases, such as are likely to thrive in a greenhouse-affected world. Yet, the gene reservoirs of crop plants are being depleted at unprecedentedly rapid rates, to an extent that already leaves our crops dependent on a critically reduced genetic-resource base.

Further, there will be pressure to grow three times as much food as today to take care of increased numbers of people with increased nutritional expectations. Yet, irrigated lands, which currently supply one-third of our food from one-sixth of our croplands, will experience reduced water flows during peak-demand seasons due to changes in water-runoff patterns in the wake of global-warming (Frederick and Gleick, 1990).

Similarly, there could be synergistic repercussions from diseases (Schneider, 1989; WHO, 1992) that readily spread among congested and impoverished communities; these communities are expected often to become all the more congested and impoverished through bearing the extra burden of refugees in large numbers. Thus, there could be prime conditions in which otherwise containable diseases could become pandemics.

These illustrations of synergistic interactions among environmental and other factors serve to point up the many amplified problems of a globally warmed world. In the face of these multifarious and multiplying problems, some communities and countries will probably be able to adapt, others probably not. The degree of probability remains a matter of judgment as long as we have scant quantified understanding of synergisms—a lacuna demonstrated by the fact that few of the previous analyses even mention the phenomenon, let alone the growing prospect, of multiple positive feedbacks in a greenhouse-affected world.

For the purposes of this article's assessment, moreover, people who will be at risk of global warming problems are considered thereby to become probable if not certain refugees. Some observers may respond that this assumption makes the current analysis a worst-case affair. I believe it is rather a real-world appraisal based largely on centre-range estimates, albeit in a situation already attended by abundant uncertainties.

In turn, a key question is raised about scientific uncertainties, with particular respect to policy responses. What is legitimate caution in the face of uncertainty, especially insofar as uncertainty can cut both ways? Some scientists may object that in the absence of conclusive evidence and analysis, it is better to stick with low estimates of refugee numbers on the grounds that they are more responsible. But note the crucial factor of asymmetry of evaluation. A low estimate, ostensibly safe because it takes a conservative view of such limited evidence as is at hand in documented detail, may fail to reflect the real situation just as much as does an unduly high estimate that is more of a best-judgment affair based on available evidence with varying degrees of demonstrable validity.

A minimalist calculation with apparently greater precision may amount to spurious accuracy. In a situation of uncertainty in which not all factors can be quantified to conventional satisfaction, let us not become preoccupied with what can be precisely counted if that is to the detriment of what basically counts. Undue caution can become recklessness; and as in other situations beset with uncertainty, it will be better for us to find we have been roughly right than precisely wrong (Myers and Simon, in press).

Aggregate Assessment

The total of environmental refugees as calculated here for a greenhouse-affected world is approximately 150 million (Table 1). However rough the reckoning, it supplies an initial insight into the scale of a major emergent problem.

Table 1. Categories of environmental refugees in a greenhouse-affected world circa 2050

Country or region	Total refugees foreseen (millions)
China	30
India	30
Bangladesh	15
Egypt	14
Other delta areas and coastal zones	10
Island states	1
Agriculturally dislocated areas	50
Total	150

This total amounts to 1.5% of the 10 billion people projected for the world's population in 2050. In contrast, the current 10 million recognised environmental refugees comprise only 0.2% of the global population of 5.5 billion.

Economic, Socio-Cultural and Political Consequences

The consequences of large numbers of environmental refugees would be among the most significant of all upheavals entrained by global warming. Refugees arrive with what are often perceived by host communities as alien customs, religious practices, and dietary habits, plus new pathogens and susceptibility to local pathogens. Resettlement is generally difficult, full assimilation is rare. Economic and social upheavals would proliferate, cultural and ethnic problems would multiply, and the political fallout would be extensive.

We are familiar enough with the strains generated for receiver nations today when they have to face throngs of refugees fleeing from drought, famine, floods, and other disasters (Chambers, 1986). To quote a former United Nations High Commissioner for Refugees, Prince Saddrudhin Aga Khan, "People flee their homes in search of food and jobs...As the victims move, they carry their famine with them, much as they might carry an infectious disease. They impose intolerable burdens in terms of food requirements in the territories they enter. At the same time, they flood the labour market, creating a slump in wages, and endangering the economic security of the local population. Fuse the two elements, and you have a perfect recipe for widespread human suffering, social disorder and political instability".

It already costs developed nations $8 billion a year to accommodate refugees. This amount is equivalent to a full one-seventh of the foreign aid they supply to developing nations. It would serve as a handsome payoff investment to boost foreign aid and tackle more of the refugee problem at the source rather than to wait and pay a higher price through responding to symptoms of the same problem.

Yet, our experience to date offers scant guidance to what could lie ahead concerning costs. As a result of sea-level rise, coastal protection costs worldwide could be on the order of $2.5 trillion to $5.0 trillion, and coastal land loss $15 trillion, making a total of $17.5 trillion to $20 trillion, spread over a period of 50 years (Ayres and Walter, 1991; see also Cline, 1992; Fankhauser, 1992; Nordhaus, 1991). The gross world product today is approximately $23 trillion. No estimate is available of the costs of disrupted agriculture in drought-afflicted regions. They could be considerable given the projected food-deficit estimates.

But the refugee reckoning should be expanded to reflect a host of other costs. There would be support costs for maintenance and resettlement. Refugees could probably not make a contribution to their host communities' economies for at least a year or two, a sizeable opportunity cost.

Many other indirect costs would be sizeable and hard if not impossible in conventional quantified terms. There would be often little land available to accommodate refugees, notably in regions with two or three times as many people as today. Refugees would tend to crowd into settlement camps or shanty towns, which would become prime breeding grounds for crime, civil disorder, social upheaval, and violence of many sorts (Ayres and Walter, 1991). As a result, there could be soaring costs to maintain security, both internal and external (Myers, 1993).

There could also be substantial outlays to counter pandemic diseases, plus deficits of food, water, and energy, together with the additional social strife and political turmoil that all these would entrain. It could often be the case that social disintegration would arrive sooner and on a larger scale than environmental breakdown. As Cline (1992) put it, "People have often fought wars to avoid being forced to leave their homelands". Moreover, these problems would often interact in such a way as to generate synergised outcomes, pushing the overall economic cost far beyond what we can realistically envisage in the light of our experience to date.

When we accord due attention to all the factors we can recognise today, plus those with which we are not yet acquainted but that may well emerge in a world altogether beyond our experience, we could suppose that the ultimate additional costs of environmental refugees could match or exceed the costs of easily identifiable and readily quantifiable problems, such as coastal protection measures and coastal land loss. As yet, we have no way of grasping what these further costs could be. It would be a mistake, however, to suppose that because we cannot even identify all these costs, let alone define, assess, and quantify them, they should therefore be left out of the current account. This issue warrants urgent research from both natural-science and social-science standpoints.

Conclusions

Today, refugees are viewed as a peripheral concern, a kind of aberration from the normal order of things. In a greenhouse-affected world of the future, they are likely to become a prominent feature of our one-Earth landscape due to the burgeoning phenomenon of environmental displacement. It requires a leap of the imagination to envisage 150 million destitutes abandoning their homelands, many of them crossing international borders. They would be all the more disruptive in a world struggling to cope with a plethora of environmental problems. Yet, amid discussions of global warming and its impacts, we hear all too little about environmental refugees.

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Using Life-Cycle Analysis to Assess Social Impacts of Energy Scenarios

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Introduction

Life-cycle analysis (LCA) is a method, by which it is possible in principle to assess all direct and indirect impacts of a technology, whether a product, a system or an entire sector of society. LCA incorporates impacts over time, including impacts deriving from materials or facilities used to manufacture tools and equipment for the process under study, and it includes final disposal of equipment and materials, whether involving re-use, recycling or waste disposal.

Whereas product LCA is used by manufacturers and regulators to select the optimal one among different products serving the same purpose, energy system and energy policy LCA may be used to handle greenhouse emission issues in a way consistently embedding the global warming issue within other environmental and social issues. In case not just individual energy systems, but national and regional energy policies have to be assessed, the LCA must be based on an assumed transition to a scenario for future energy supply, transmission, conversion and use.

These remarks define the issue of the present paper, linking issues of global development, scenarios for future energy use, and finally political assessment with the assistance of LCA as a tool.

Identification of Life-Cycle Impacts

The impacts that one would like to include in an LCA are likely to depend on time and place of assessment. However, in broad terms, they may be grouped into the following categories (Sørensen, 1993b):

Economic impacts such as impacts on owners economy and on national economy, including questions of foreign payments balance and employment distribution.

Economy is basically a way of allocating scarce resources. Applying economic assessment to an energy system, the different payment times of different expenses have to be taken into account, e.g. by discounting individual costs to present values. This again gives rise to different economic evaluations for an individual, an enterprise, a nation, and some imaginary global stake holder. One possible way of dealing with these issues is to apply different sets of interest rates for the above types of actors, and in some cases even a different interest rate for short-term costs and for long-term, intergenerational costs, for the same actor.

Precursors to these kinds of economic evaluation are the separate private economy (sometimes referred to as direct economy) and national economy accounts often made in the past. The national economy evaluation includes such factors as import fraction (balance of foreign payments), employment impact (i.e. distribution between labour and non-labour costs), and more subtle components such as regional economic impacts.

Environmental impacts, e.g. land use, noise, visual impact, local pollution of soil, water, air and biota, regional and global pollution and other impacts on the Earth-atmosphere system, such as climate change.

Environmental impacts include a very wide range of impacts on the natural environment, including both atmosphere, hydrosphere, lithosphere and biosphere, but usually with the human society left out (but to be included under the heading social impacts below). Impacts may be classified as local, regional and global.

At the resource extraction stage, in addition to the impacts associated with extraction, there is the impact of resource depletión. In many evaluations, the resource efficiency issue of energy use in resource extraction is treated in conjunction with energy use further along the energy conversion chain, including energy used to manufacture and operate production equipment. The resulting figure is often expressed as an energy pay-back time, which is reasonable because the sole purpose of the system is to produce energy, and thus it would be unacceptable if energy inputs exceeded outputs.

In practise, the level of energy input over output that is acceptable depends on the overall cost, and should be adequately represented by the other impacts, which presumably would become large compared with the benefits, if energy inputs approached outputs. A low extraction efficiency can well be accepted, if the resource is free or nearly free (e.g. solar radiation). In other words, energy pay-back time is a secondary indicator, which should not itself be included in the assessment, when the primary indicators of positive and negative impacts are sufficiently well estimated.

Also issues of the quality of the environment as seen from an anthropogenic point of view, should be included here. They include noise, smell and visual impacts associated with the cycles in the energy activity. Other concerns include the preservation of natural flora and fauna.

Social impacts, related to satisfaction of needs, impacts on health and work environment, risks, impact of large accidents, institutions required.

Social impacts include the impacts from using the energy provided, which means the positive impacts derived from services and products arising from the energy use (usually with other inputs as well), and some negative impacts associated with the energy end-use conversion. Furthermore, social impacts derive from each step in the energy production, conversion and transmission chain. Examples are occupational health issues, work environment, job satisfaction, and risk, including the risk of large accidents. Another area of potential social impacts are in the institutional set-up of the systems providing energy of a certain kind: types of organisations, financing schemes, and so on. Some of these issues connect to those mentioned below under the heading "political impacts".

Security impacts, including both supply security and also safety against misuse, terror actions, etc.

Security can be understood in different ways. One is supply security, and another the security of energy installations and materials, against theft, sabotage and hostage situations. Both are relevant in a life-cycle analysis of an energy system. Supply security is a very important issue for those energy systems depending on fuels unevenly spread over the planet. Indeed, some of the most threatening crises in energy supply have been related to supply security (1973/74 oil supply withdrawal, 1991 Gulf War).

Resilience, i.e. sensitivity to system failures, planning uncertainties and future changes in criteria for impact assessment.

Resilience is also a concept with two interpretations: one is the technical resilience, including fault resistance and parallelism, e.g. in providing more than one transmission route between important energy supply and use locations. Another is a more broadly defined resilience against planning errors (e.g. resulting from a misjudgment of resources, fuel price developments, or future demand development).

A more tricky, self-referencing issue is resilience against errors in impact assessment, assuming that the impact assessment is used to make energy policy choices. Many of the resilience issues are connected to certain features of the system choice and layout, including modularity, unit size, and transmission strategy. The possible use of an impact awareness escalation rate has been suggested by Rabl (1994).

Development impacts (e.g. consistency of a product or a technology with the goals of a given society).

Energy systems may exert an influence on the direction of development a society will take, or rather may be compatible with one development goal and not with another goal. These could be goals of decentralisation, goals of concentration on knowledge business rather than heavy industry, etc.

For so-called developing countries, clear goals usually include satisfying basic needs, furthering education, and raising standards. Goals of industrialised nations are often more difficult to identify. Often emphasis on agriculture, industry and export are ingredients in the strategies of developing countries. The positive or negative impact of a given energy system on these goals constitute development or political impacts.

Political impacts include e.g. impacts of control requirements, and on openness to decentralisation in both physical and decision-making terms.

There is a geo-political dimension to the above issues: development or political goals calling for import of fuels for energy may imply increased competition for scarce resources, an impact which may be evaluated in terms of increasing cost expectations, or in terms of increasing political unrest (more "energy wars").

The political issue also has a local component, pertaining to the freedom or lack of freedom of local societies to choose their own solutions, possibly different from the one selected by the neighbouring local areas.

It is clear that a list of the kind given above is open-ended, and that some impacts will never become quantifiable.

On the other hand, weighing of incommensurable impacts is precisely what the political decision-making process is about. If the LCA impacts of each system could be expressed as a single number, one might as well let the computer choose the solution with the smallest negative impacts. But because the impacts are of different kinds, our value systems and preferences, as well as some democratic playing rules are needed, in order to reach an agreement on the choice of system. This raises new problems of how to present and use an LCA, which would typically produce a list of impact estimations, some of which quantified and some not, and with the quantifiable impacts often given in quite different units (e.g. tons of sulphur dioxide, number of work accidents, capital cost of equipment).

One philosophy is to try to convert all impacts into monetary values, i.e. replace the sulphur dioxide amounts with either the cost of reducing the emissions to some low threshold value (avoidance cost) or alternatively an estimated cost of the impacts: hospitalisation and workday salaries lost, replanting cost of dead forests, restoration of historic buildings damaged by acid rain. Accidental death would be replaced by the insurance cost of a human life, and so on (damage costs). Unavailability of numbers has led to the alternative philosophy of interviewing cross sections of affected population on the amount of money they would be willing to pay to avoid a specific impact or to monitor their actual investments (revealed preferences, willingness to pay). Such a measure may change from day to day, depending on exposure to random bits of information (whether true or false).

All of these methods are deficient, the first by not including a (political) weighing of different issues (e.g. weighing immediate impacts against impacts occurring in the future), the second by doing so on a wrong basis (influenced by people's knowledge of the issues, by their accessible assets, etc.). The best alternative may be to present the entire impact profile to decision-makers, in the original units and with a time-sequence indicating when each impact is believed to occur, and then to invite a true political debate on the proper weighing of the different issues.

The difficulties encountered in using LCA in the political decision-making process have been partly offset by the advantages of bringing the many impacts often disregarded (as "externalities", meaning issues not included in the economic analysis) into the debate. It may be fair to say that LCA will hardly ever become a routine method of computerised assessment, but that it may continue to serve a useful purpose by focusing and sharpening the debate involved in any decision-making process, and hopefully help increase the quality of the basic information, upon which a final decision is taken, whether on starting to manufacture a given new product, or to arrange a sector of society (such as the energy sector) in one or another way. Examples of actual energy system LCAs are given towards the end of the paper.

The Current Development Scene

The recent collapse of a number of conservative communist regimes with a sterile top-down control structure and inherent conservatism has led to a reassessment of development models, both in currently industrialising countries and in economies yet to choose their path of development.

There has been a surge of efforts to reinstate and spread a variety of liberalism based upon nineteenth century crude versions of market controlled economies with minimal roles accorded to governments. This situation makes it very important for leaders responsible for national development strategies to keep their heads cool and take a more comprehensive view of the issues.

An alternative development model used to be suggested by the Scandinavian countries. Central in the Scandinavian way of thinking was a necessity for looking at things with global eyes, and an ability to feel uncomfortable when confronted with a strongly unequitable distribution of assets and opportunities. However, the set of values promoted by particularly the United States of America have recently set themselves through in many other parts of the world, including Scandinavia. The advocates are often economists basing their advice to decision-makers on a partial model of society, and yet pretending that the prevailing economic theory is a universally valid science. In reality it hardly deserves to be called a science, but rather constitutes a codification of some particular views regarding social power structures, according e.g. to Blatt (1983) and Eichner (1983).

In order to develop more comprehensive alternatives to the atavistic economic descriptions of current development options, it is an urgent priority to look for consistent alternative social and economic models, which on one hand avoid inviting to the power concentration and the curtailment of development initiatives that accompanied the transition from socialism to communism, and on the other hand offer a clear break with the primitive liberalism dominating at present.

The Third Way

The basis for an alternative way of shaping national policies may involve a technique known as the scenario method. It basically consists in selecting a few of the possible futures, chosen on the basis of having spurred an interest in the population and by reflecting different values held in a particular society.

As the next step, these futures have to be modelled, with emphasis on the issues deemed particularly important: better social conditions, less polluting energy systems, environmentally sustainable processes, societies offering human relationships within a preferred frame, and so on. During this process one must keep in mind, that models are simplified and necessarily inaccurate renditions of reality, and have to be treated accordingly. Models are essentially frameworks for discussion.

One would next have to discuss the consistency of the elements in the models, e.g. as regards sustainability, resource availability, and consistency between different aspects of the scenario. And finally discuss possible paths from the present situation to the scenario future. This would be done for each scenario proposed, as part of an assessment which involves the full apparatus of political debates and decision-making processes.

Central questions to address are who should propose the scenarios and who should stage the debate and decision process. There are clearly many possibilities for manipulation and unfair representation of certain views. Whether a democratic process can be established depends on the level of education and understanding of the decision process, by the citizens of a given society, as well as on the tools used for debate, including questions such as fairness of and access to media. Many developed countries have a tradition for broad social debates, but even in such countries, there are also clear efforts by interest groups or sitting governments to take over the communication means and distorting the process in favour of their own preferred solutions. These institutional questions have to be part of any realistic proposal for a new way of approaching development issues (cf. Fig. 1) .

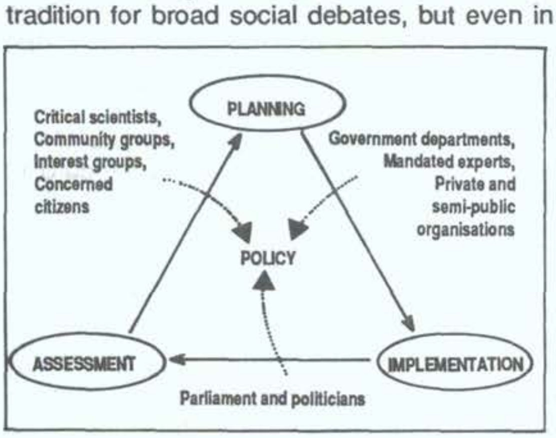

Fig. 1. The actor triangle, a model of democratic planning, decision-making and continued assessment (Sørensen, 1993a).

An Example of Scenario Technique Applied to Energy Planning

In order to illustrate the issues involved, scenarios of energy demand are first presented from a global perspective, and then exemplified for Denmark in order to present an already worked out energy system construction amenable to assessment by life-cycle analysis.

Demand Models

The bottom-up approach for determining energy demand (Sørensen, 1981b, 1984, 1988) is based on a model in which all basic needs are to be covered (food, shelter, human interaction), and furthermore a broad selection of secondary needs, that may be selected differently by different societies and by different individuals (activities, relations, possessions). The needs are then analysed in terms of energy inputs, recognising that in many cases, the same products and services can be produced in different ways, characterised by highly different inputs of materials and energy (Fig. 2).

The outcome of this analysis is, that over a broad range of secondary needs selections, geographical locations (important for heating and cooling needs) and settlement types (from dense cities to dispersed living), the required average flow of energy inputs are in the range of a half to two kW per capita except for extremely cold climates. This assumes using the best technology known at present. Fifty or a hundred

Fig. 2. Energy conversion chain (Sørensen, 1988).

years ago, the numbers would have been higher (if the same needs could have been delivered), and in the future, new technological breakthroughs may make the numbers lower. Particularly as regards the low-temperature heat use, a wealth of options are available, including heat pumps and heat cascading.

Figure 3 gives an overview of energy flows, divided on energy qualities and broad classes of activities. Note that the bottom-up approach implies, that the desired human activities constitute the driving force, and that production of goods and services becomes a derived quantity, the size of which depends entirely on the specification of needs. The societies are not assumed to produce goods blindly, in the hope that a demand can be created, once the goods are brought to the market. Again this is a Scandinavian way of looking at the production process, very different from the primitive market picture prevailing in e.g. Anglo-Saxon countries. However, different societies may place emphasis

	1. Cooling and refrigeration	2. Space heating	3. Process heat under 100°C	4. Process heat 100–500°C	5. Process heat over 500°C	6. Stationary mechanical energy	7. Electric appliances	8. Transportation work	9. Food energy	TOTAL
A. Biologically acceptable surroundings	0–24	0–1500	0	0	0	0	0	0	0	*0–1524*
B. Food and water	14–24	0	15	2–6	0	0	0	0	120	*151–165*
C. Security	(0)	(0)	0	0	0	(0)	0	(0)	0	*(0)*
D. Health	0	0	80–150	20–40	0	0	(0)	(0)	0	*100–190*
E. Relations, leisure	(0)	(0)	0	0	0	0	10–60	25–133	0	*35–193*
F. Activities: Construction	0	0	0	0	0	30–60	0	7–15	0	*37–75*
Trade, service and distribution	1–8	0–600	0–12	0	0	6	10–20	30–70	0	*47–716*
Agriculture	0	0	2–12	0	0	3–6	0–2	3–6	0	*8–26*
Manufacturing industry	1–16	0–600	10–100	20–70	12–30	20–60	15–30	7–15	0	*85–921*
Raw materials & energy industry	0	0	0–30	0–20	0–250	0–170	0–30	0–20	0	*0–520*
Education	0–2	0–160	0	0	0	0	1–2	0	0	*0–164*
Commuting	0	0	0	0	0	0	0	0–30	0	*0–30*
TOTAL	*16–74*	*0–2860*	*107–319*	*42–136*	*12–280*	*59–302*	*36–144*	*72–289*	*120*	*464–4524*

Fig. 3. Scenario for the rate of end-use energy needed for satisfying goals in different societies at different geographical locations (W per cap) (Sørensen, 1984, 1988, 1994).

on different types of production (basic materials, consumer goods, agricultural products, knowledge-based services, and so on). This is what gives rise to the wide ranges of possible energy use in the activity sectors.

Figure 4 gives a specific example of the demand matrix of Fig. 3, to be used for the energy supply model considered in the following section and pertaining to a scenario for Denmark attempting to catch some important traits of Danish preferences (Sørensen, 1994).

Among the energy demand models that could be considered, there would generally be growth and saturation models. By this is understood growth and saturation in services and production, which again may or may not lead to growth in energy demand, depending on the cost of energy systems as compared with other factors in the economy. Historically, short periods of growth have been followed by long periods of saturation on various levels, both for production and energy use (Sørensen, 1979).

	1. Cooling and refrigeration	2. Space heating	3. Process heat under 100°C	4. Process heat 100–500°C	5. Process heat over 500°C	6. Stationary mechanical energy	7. Electric appliances	8. Transportation work	9. Food energy	TOTAL
A. Biologically acceptable surroundings	0	260	0	0	0	0	0	0	0	260
B. Food and water	18	0	3	6	0	0	0	0	120	147
C. Security	0	0	0	0	0	0	0	0	0	0
D. Health	0	0	100	24	0	0	0	0	0	124
E. Relations, leisure	0	0	0	0	0	0	54	36	0	90
F. Activities: Construction	0	0	0	0	0	60	0	15	0	75
Trade, service and distribution	6	120	12	0	0	6	18	48	0	210
Agriculture	0	0	12	0	0	6	2	6	0	26
Manufacturing industry	15	106	12	10	10	60	30	15	0	258
Raw materials and energy industry	0	0	12	10	10	30	12	15	0	89
Education	0	26	0	0	0	0	2	0	0	28
Commuting	0	0	0	0	0	0	0	15	0	15
TOTAL	39	512	151	50	20	162	118	150	120	1322

Fig. 4. Scenario for the rate of Danish energy use at the end-user in year 2030 (W per cap) (Sørensen, 1994).

Present arguments for or against growth both refer to third world development: One side claims that economic growth will make the cake to share larger and everybody happier, while the other side says that growth will create stronger competition for scarce resources, and that will hurt the regions trying to develop. The actual development trends over the latest decades in some areas support the second view, and it is not difficult to argue in general terms, that global claims on the resource base do not seem to promote equity, but certainly helps in creating hostility and cause warfare (problem of fundamentalist movements, oil wars).

It is important to stress, that one can have growth in the economic sense without the associated growth in resource usage: If the main growth is in intellectual activities and services, the physical growth can be zero or negative, while the economy may continue to flourish, remembering that economic indicators such as GNP only measure the level of *activity*. The scenario depicted in Figs 3 and 4 assumes a future society with increased emphasis on environmental sustainability, low and efficient resource usage and growth in those activities expected in an information-society (Porat, 1977; Valaskakis and Fitzpatrich-Martin, 1988).

Bottom-up Construction of Energy Systems

Once the energy demand structure is given, the modeller's task is to construct a supply, conversion and delivery system capable of satisfying the demand at the end-users. The selection of the system depends on the technologies available, but also in some cases on preferences between different system-layouts, of which one is not clearly superior to all the other ones. Typically, the life-cycle impacts of different types of system are so different, that some groups in the society have clear preferences for one solution and feel that they would not like to live with some of the other solutions, while other groups in the society may feel just the opposite way.

In such cases, one could possibly give high priority to options involving a decentralisation, that would allow different subgroups in a society to select different solutions, rather than going for centralised solutions bound to make some fraction of society unhappy. That this is possible hinges on the recent development of decentralised solutions without cost penalties, i.e. that technology has entered a stage, where the economy of scale is less important than it was some decades ago.

The technique for constructing the energy system may consist in tracing the system back from the end-user, but as it will become clear, this is not always possible, and some tracking back and forth between supply and demand may be required. At each end-user, one may first consider the options for local energy production, such as solar heat, solar cells, building-size fuel cells, and so on. When intermittent production is included, the question of load-matching and energy storage has to be considered. Some such storage may be located at the end-user. Current examples are batteries for portable equipment and heat stores for solar thermal collection systems. In a wider perspective, also load-management has to be considered, such as deference of non-urgent tasks, within time-limits accepted by the user and possibly reflected in his/her cost of energy.

On the supply side, there might be installations characterised by a large fraction of the cost tied up in equipment (e.g. wind turbines, photovoltaic panels), but for which the operating cost is very small. Such equipment should have priority, once it is part of the system, and if the energy generation is also intermittent, these installations have to be dispatched before others that may be regulated. This means, that such priority equipment has to be considered up front, also in cases where it is not located near the user, and thus transmission and any further conversion to other energy forms should be determined at this stage. There may also be options for central storage in the system, that can take care of surplus production from priority sources. If not, any overflow must be exported or will be lost.

In principle, the modeller works backwards from the end-user over transmission and conversion equipment to the primary energy source inputs, but with the above-mentioned priority sources as bound options. In some systems, the delivery paths in place (gas, electricity and heat transmission lines) determine which energy flows can be directed at particular groups of end-users, but in many cases, there would be more than one option for generating the various energy forms then demanded. This defines the dispatch problem, where a routine must be found for selecting the succession of generating equipment and feeding energy sources, that will be employed at any given moment.

This selection may be based on a ranking of the sources (e.g. in terms of generating costs), but often there is more than one solution satisfying any simple criteria. This is certainly the case, if the system comprises storage and import/export options in various places between supply and demand. One of the criteria to consider is security of supply, meaning that one minimises the risk that, e.g. stores are empty when they are unconditionally needed (especially relevant for systems with a high fraction of intermittent sources).

It is important to distinguish between systems modelling aiming at proposing an optimal system layout, i.e. which components to build, and modelling aimed at utilising a given system optimally, by selecting the best dispatch pattern. These two aspects may be combined in a dynamic simulation of the system, where one tries to identify the signals, that should lead to decisions to add components to the system (or phase out components), with given lead times between decision and operability of the new components.

Figures 5–7 give an overview of a preliminary version of a scenario for a future Danish energy system based upon renewable energy sources and the demand scenario of Fig. 4 (Sørensen, 1994).

It assumes a wind contribution based on a number of 2 MW turbines similar to the present number of smaller machines, and that roughly a quarter of all buildings have solar thermal or photovoltaic collectors. The contribution from biomass include gas and liquid fuels, and is based on the already started transition in the Danish agricultural sector, where a smaller area will be used only for food production, yielding however the same export of refined products but a balance considered more healthy between animal and vegetable products for indigenous consumption. The biomass for energy purposes are partly derived from better utilisation of current "waste", partly from dedicated energy crops. However, the total cultivated area is not expanded from its present value.

Figure 7 details the flows in the agricultural sector, while Fig. 5 treats the rest of the system leading to the end-users. Figure 6 explains the nomenclature used in Fig. 5. The scenario is preliminary, as the dynamical simulation of the supply-demand matching has not yet been performed, but only the overall balancing of flows. However, it gives an example of a system taking advantage of the current transmission network for electricity, gas and heat, and at the same time removing fossil fuel inputs and their greenhouse emissions over a 30-year period, with minimum requirement for long-term energy storage (although the system does comprise heat stores, gas stores in aquifers and salt domes, and a little electricity storage capacity in batteries and compressed gas stores).

It is assumed that the interconnection with the European power grid will take care of any further mismatch between electricity production and local demand. This involves some imports and exports, judged to be beneficial to both partners in the exchange. For example, the exchange with countries such as Norway possessing large seasonal hydro stores allows for taking care of day-to-day mismatch, while adding to the resilience of the Norwegian system towards coping with particular dry years, a function which today is taken care of by the Danish fossil fuel power stations (Sørensen, 1981a).

In the transportation sector, the scenario for year 2030 assumes, that only electric vehicles are allowed in cities, and that long-distance

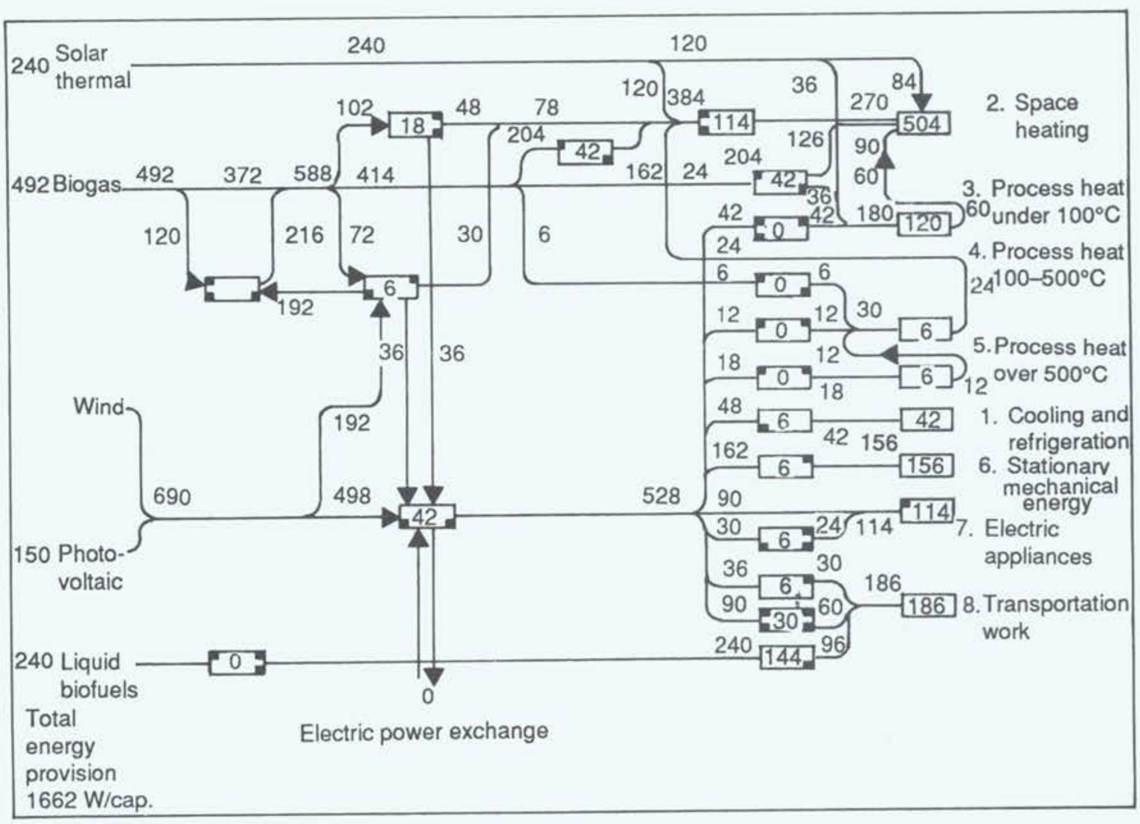

Fig. 5. Scenario for a renewable energy based system for Denmark anno 2030 (W per cap.) (Sørensen, 1994).

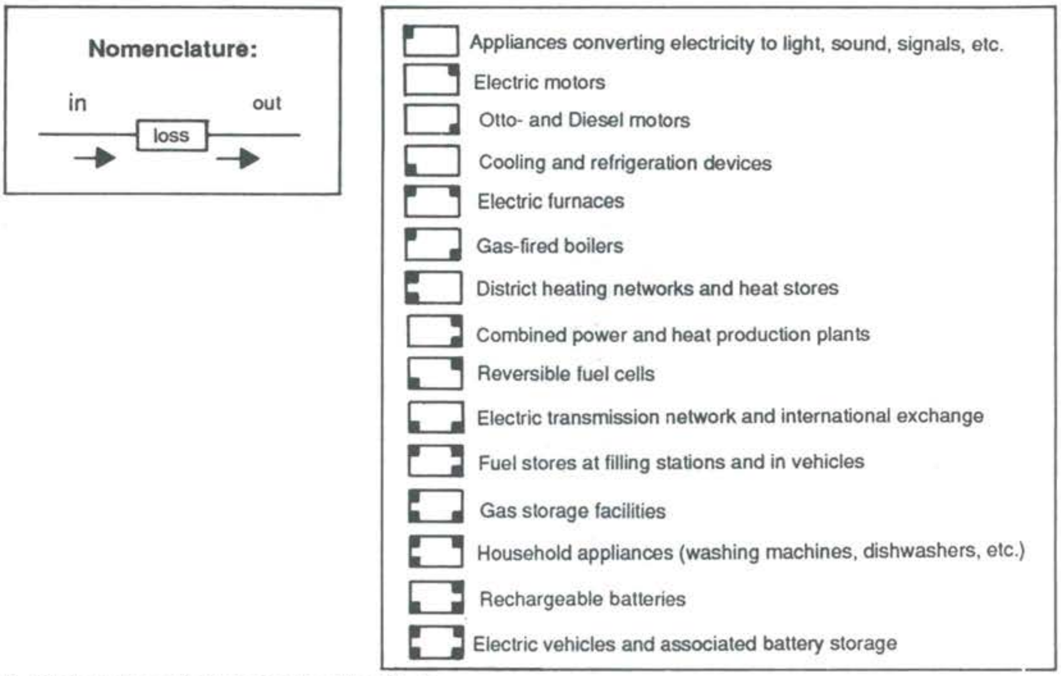

Fig. 6. Explanation of symbols used in Fig. 5.

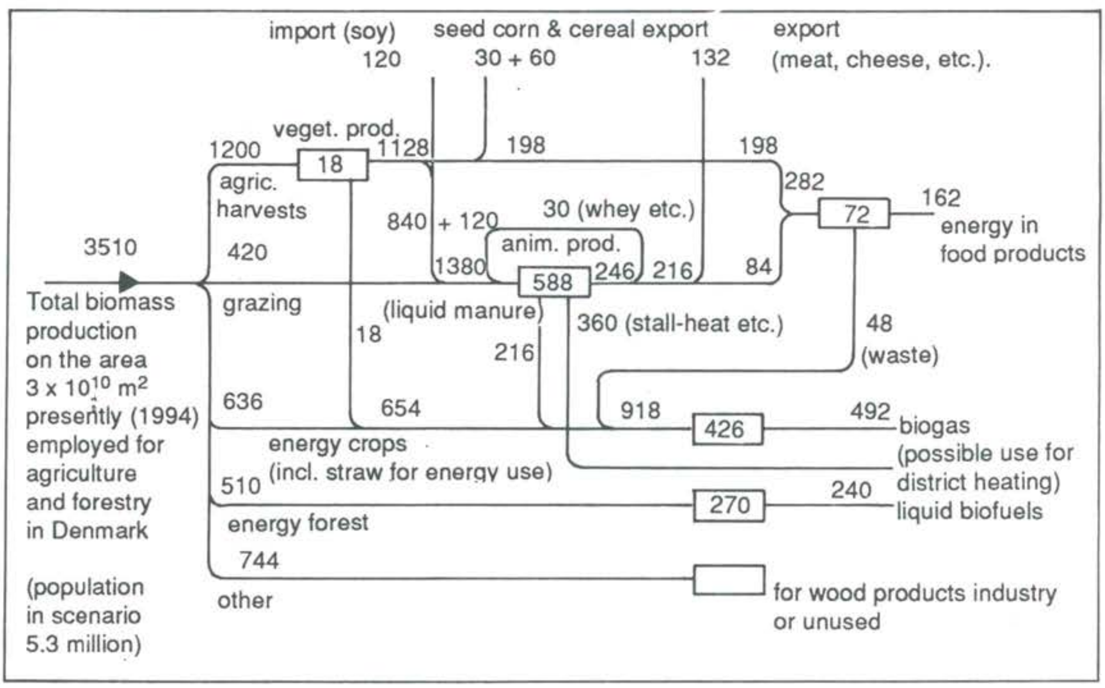

Fig. 7. Scenario for Danish biomass sector anno 2030 (indirect energy inputs through chemical fertilisers etc. not included).

transport of goods and people will be based on biofuels.

Implementation of Life-Cycle Analysis for Renewable Energy Systems

The examples of LCA assessment given below is for selected energy technologies, such as wind and photovoltaics, characterised by near absence of climate effects (depending on where the materials used and energy inputs to manufacturing comes from). For comparison, an assessment of coal-based power is added, with its strong climatic impacts. One purpose of LCA is of course to provide a full impact overview, such that the higher direct cost of many renewable energy solutions may be weighed against the lower indirect impacts. An LCA assessment of a complete future scenario of energy supply, such as the one given in the previous section for Denmark, is underway but will not be reported here. Now a few practical remarks:

In a practical implementation of LCA, each impact is initially presented in units relevant for the category in question. In presenting the impact profiles derived in this way to decision-makers, a scale of -1 to 1 may be used, because the weighing of incommensurable impacts will anyway involve the decision-maker's choice of weight factors. It may seem, that the accuracy of this approach is lower than if physical units (such as death per kWh or kilos of SO_2 per kWh) had been used. However, this is not necessarily the case, since the precision with which the physical data can be given is quite consistent with a fairly coarse indication, allowing a resolution of perhaps less than ten levels in the range of impacts being evaluated as negative over neutral to positive. It is also possible to include non-linearities in the criteria adopted. At the extreme these could be the labelling of some impacts as unconditionally unacceptable (Sørensen, 1993b).

Wind Turbines and Silicon Solar Rooftop Modules

The wind turbine analysis (Sørensen, 1993c) presented in Fig. 8 pertains to Danish turbines currently produced and locally installed. It is realised that several of the impacts exhibit a dependence on the natural, social and human setting. Thus one should be careful in transferring data to other settings than the Danish one. The penetration of wind power in the Danish electricity system is currently 4–5%. If penetrations above some 20% were achieved, the question of energy storage would have to be addressed. However, given the strong international links, e.g. to the Norwegian hydro system based on annual storage cycles, the cost of dealing with the variability of wind energy production could turn out to be very low (Sørensen, 1981c).

The manufacture of photovoltaic cells is today barely suitable for generic assessment. Some mass-scale production is taking place, but the technology continues to change, as it has to in order to approach a price level catering to major market segments such as bulk power production. Furthermore, the worldwide industrial capacity is currently not fully used, and this slows down an introduction of improvements that are already identified and ready for implementation. Some of these improvements are known to lead to substantial improvements in conversion efficiency, while others reduce the manufacturing cost and at the same time reduce the environmental impacts of cell and module manufacture.

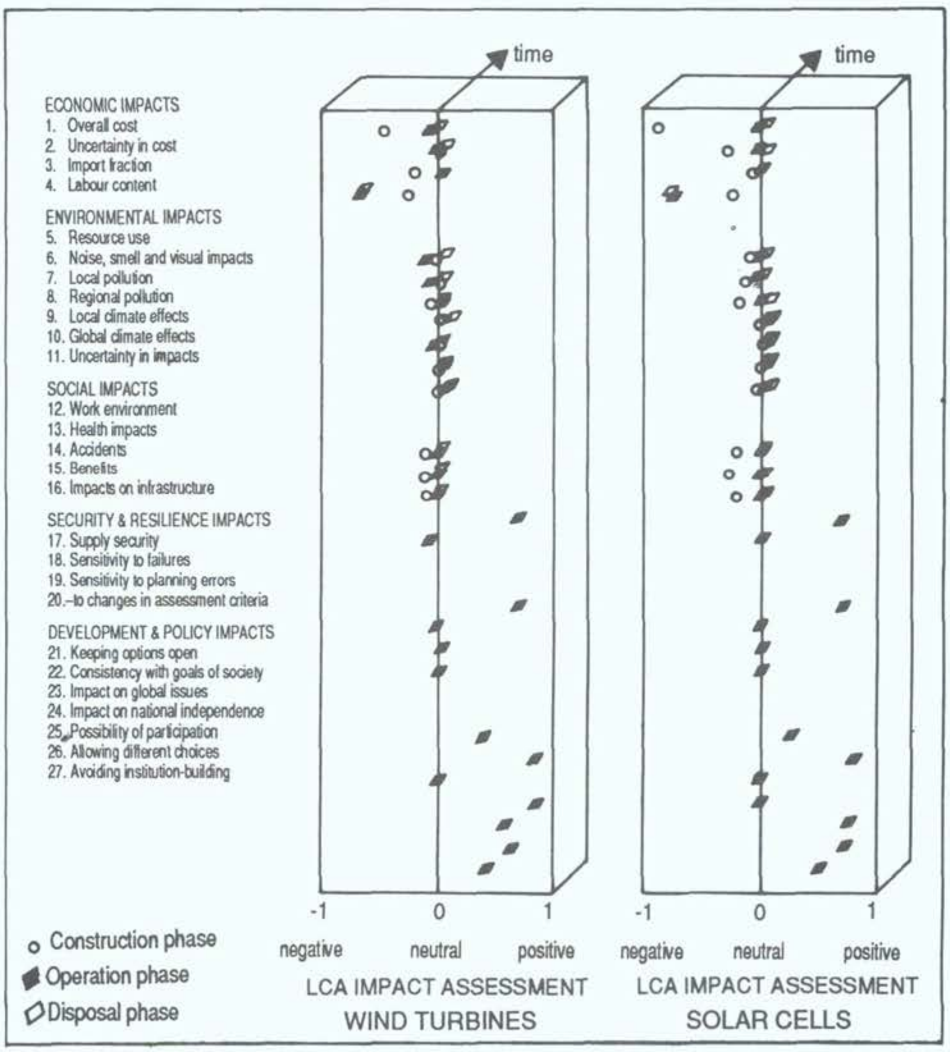

Fig. 8. Life-cycle assessment of wind and solar cell systems, expressed in arbitrary units.

The life-cycle analysis presented in Fig. 8 (Sørensen, 1993c; Watt and Sørensen, 1993) pertains to the current manufacturing technology for silicon-based cells. These comprise the substantially different technologies of crystalline and amorphous cells, and of solid or thin-film techniques. When impacts depend on these differences, it will be pointed out. Furthermore, there are several differences between the impacts of modules for centralised power plants, and those aiming at decentralised use, integrated into building structures such as roofings. One of these differences has to do with the possibility of using concentrator cells and tracking devices, while other obvious differences have to do with area use. Also the possible modularity of electricity conditioning equipment such as inverters may differ.

The present analysis assumes non-concentrating cells in modules mounted on individual buildings. Cell and module fabrication is assumed to take place in the country using the modules, and the penetration of the technology plus the structure of the residual electricity supply system is assumed to be such, that no particular requirements for energy storage arise in conjunction with the photovoltaic panels. The main steps in the life-cycle of photovoltaic devices are depicted in Fig. 9.

Impacts

The overall cost of producing wind energy in Denmark is currently about 35 øre/kWh (5 US cents per kWh), with O&M constituting an average of 7 ø/kWh (1 c/kWh) out of this, averaged over an assumed 20 year lifetime. Because the capital cost is dominating, there is much less uncertainty in cost after the turbine is installed, than there would be for a fuel-based system. The import fraction of the capital cost is 28%, that of the running cost 15%. The employment factor is about 3 (full-time equivalent per million Danish Kr. spent). Labour is considered a negative impact in Fig. 8, but it might be viewed as a positive attribute by some societies (with activity deficiency or inefficient distribution of wealth), especially in times of unemployment. In any case, creating jobs within a society is often viewed as preferable compared with creating jobs abroad.

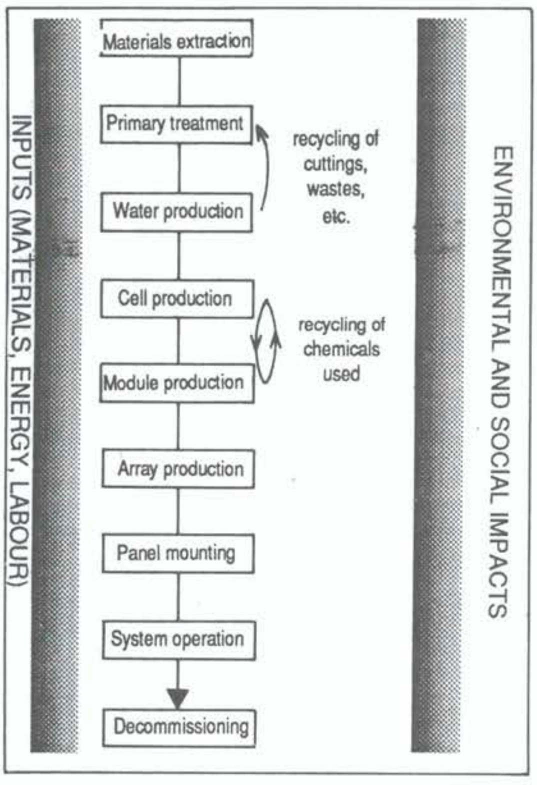

Fig. 9. Main steps in PV life-cycle.

Current cost of photovoltaic power is about 40 US cents per kWh, but expected to fall to around 10 c/kWh early in the next century. Of the 40 c/kWh, about 25 c derive from module capital cost and 1 c from O&M, the rest being balance of system (BOS) capital cost. The projection would be for around 6 c/kWh for the modules and 3 c/kWh for the BOS in the rooftop mounted case, assuming integrated PV-building elements or thin-film modules glued onto a cheap substrate building element. No installation cost apart from electric connection is included, assuming that mounting costs are the same as for other roofing elements. The national economy items are similar to those of wind turbines, except for the higher labour content associated with the higher cost.

Danish wind turbines are placed both in park configurations and individually. The land between them and right up to the towers may be used for agriculture, so that the largest cost in terms of land-use is often the access roads needed for service purposes. Typical values are 10 m^2 per kW rated power. Land resources may be returned after decommissioning.

The mechanical noise from Danish wind turbines is below current minimum regulatory limits (35dB(A) in the audible range, and about 70 dB(A) for infrasound) a few rotor diameters away from the turbine. Aerodynamical noise from the blades is similar to that of other structures or vegetation. Telecommunication interference has been studied and found similar to that of static structures (e.g. buildings).

The extraction of power from the wind has a slight influence on the microclimate below and behind the turbines, but otherwise the pollution associated with the operation of wind turbines is limited to minor issues such as oil used for greasing. The main potential source of pollution is the manufacture and maintenance operations, which are subject to the usual industrial regulation. The work environment at manufacturers of windmill components is similar to that of other equipment manufacturers, while the work environment for tower building, assembly and maintenance is similar to that of work in the building industry, with lots of open air activities and scaffold work at a height. With proper safety precautions, such work is generally offering a varied and challenging environment.

Health problems are primarily present in the industrial part of manufacture, including in particular the use of epoxy resins in blade manufacture. Modern production lines have confined this step of production to closed spaces with fully automated facilities, implying that employees only do control-room work, and that the risk of exposure to harmful chemicals is basically an accident risk. Eighteen years of blade manufacturing experience has proven that the accident risk can be kept extremely low.

The use of dedicated land resources is zero for rooftop mounted solar panels. Silicium is abundant everywhere, in the form of silicon dioxide, but as for any mining operation, its extraction may affect the natural environment. The operation of solar panels is without noise or smell, but the integration of panels in buildings does require architectural skills in order to produce acceptable visual impacts.

The industrial handling of silicon, throughout the steps of production, all involve potential pollution of the environment, unless all materials used are accounted for and recycled (Watt and Sørensen, 1993). The processes involved are typical of many chemical/mechanical industries or particularly of the semiconductor industry, so one may use data from that industry in the analysis.

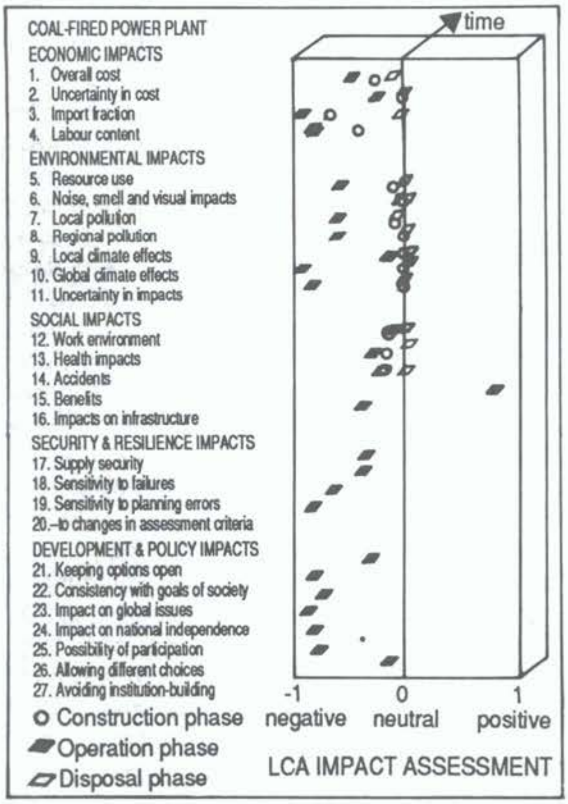

Fig. 10. Life-cycle impacts of coal power life-cycle.

Social benefits derive from the electricity produced. Both wind and photovoltaic energy can have impacts on the infrastructure of the electricity supply system, because of the dispersed mode of production, that may lead to reduced demands for the power transmission.

The work environment for solar cell manufacture involves the risk of exposure to a range of dangerous chemicals. Most have analogies in the semiconductor industry (Watt and Sørensen, 1993). On the other hand, few impacts are expected during operation of PV systems or their retirement.

Security of supply from both wind turbines and solar cells is generally high, with the qualifications related to the variability of the resource. The modular nature of the systems make individual failures less important. Because of the short time lag between deciding to build the system, and its operation, the renewable energy technologies considered have much less sensitivity to planning errors (e.g. wrong forecast of future loads), and changes in criteria used for selecting technology, than systems with several years lag between decision and operation.

For both wind and particularly for building-integrated solar cells, a decentralised decision process and local control are readily possible.

Comparison with a Conventional Fuel-Based System

The impact profiles of Fig. 10 are in many ways typical of renewable energy systems. It is therefore relevant to place them in perspective, by comparing them to the profiles pertaining to conventional fuel-based systems. Figure 10 shows such a profile, for electric power produced by a large coal-fired plant. Data pertains to the Danish level of particulate removal, SO_2 scrubbing etc. (Sørensen, 1993c).

The profiles exhibit, in addition to the well known differences between fuel-based and renewable energy systems, in economic impacts, a number of stark differences in all other impact areas, which strongly favours the renewable energy solutions.

Concluding Remarks

The purpose of the present article has been to demonstrate some of the working methods presently characterising the field of energy and environment, and to place them in the context of the IPCC work on greenhouse effect mitigation and development. This in particular involves the identification of assessment methods, that retain not only conventional economic, but also environmental and social impacts from energy activities. The scenario methods linked to LCA are offered as the likely best candidates for political assessment in this field.

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Equity Considerations in the Climate Debate: Technology Transfer

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Background: The Basic Issues

The relationship between technological change and economic growth is a critical factor in national development, in both the Third World and the industrialised nations.[1] This point has been clearly illustrated by the role of information technologies, intellectual property rights, and by the varying degrees of technological capability depending on the particular economic systems. The North and the South have complex relationships that cut across such phenomena as the environment, agriculture, and population growth. But, in these relationships there are certain puzzles. One of these arises from the fact that the North controls advanced technologies, which the South noticeably needs: Yet, issues pertaining to environmentally-sound technologies are invariably considered to be an integral part of any policy that is designed to achieve sustainable development, whether at the global or the national level.[2]

Technology transfer between developing and industrialised countries has mainly been seen as an issue affecting the economic prosperity of the developing countries. Technology is inextricably linked with economic growth, and thus holds the key to enhanced productivity in the developing countries. However, besides technological change for greater productivity, there are other no-less important concerns in development: For instance, the cultivation of science, and of social and cultural norms that are necessary for equitable resource allocations. The developing countries must seek technological change in a policy context in which such normative and social matters are taken into account.

In international economic relations, there have been many endeavours, aimed at obtaining essential industrial inputs.[3] The objects have been largely commercial; and they have stretched the natural resource base beyond the limits of sustainability. Modern concerns for development must, as a result, address certain vital questions, such as mechanisms for restoring the ecological base; managing the environment; conserving the biological resources; reducing the emissions of greenhouse gases; providing substitutes for chlorofluorocarbons (CFCs) all these while at the same time enhancing economic growth and development. Technological options for reducing methane (CH_4) emissions from oil and natural gas systems,[4] and technical change for manufacturing substitutes for CFCs are creating hope for the possibility of securing environmentally-sound technologies. If such hope is realised, there would be the possibility of technology transfer involving capital goods, services, and design specifications; skills and knowledge for production; knowledge and expertise for generating and managing technical change;[5] and all this would provide the medium for imparting knowledge and skills necessary for equitable resource allocation, and for environmental management.

The quest for technology should not disguise the fact that the term incorporates both foreign technology and local technology. Even as the international community attempts to develop legal and commercial mechanisms to promote transfer of technologies to developing countries, local capacity in these countries should be developed, so as to enable them to make better choices, on the basis of a judicious technology assessment.

[1]Skolnikoff E. B. (1993) *Science, Technology and the Evolution of International Politics*. Princeton University Press, Princeton, New Jersey, USA.

[2]Juma C. (1994) "Environmentally Sound Technology Development and Transfer". African Centre for Technology Studies (ACTS), Nairobi, Kenya.

[3]World Commission on Environment and Development (WCED), (1987) *Our Common Future*. Oxford University Press, New York, USA. Pg. 67.

[4]US/Japan, January 1992, Working Group, Background Document on Technological Options for Reducing Methane Emissions.

[5]Juma C. (1994) "Promoting International Transfer of Environmentally Sound Technologies: The Case of National Incentive Schemes", ACTS, Nairobi, Kenya.

There are certain severe limitations to technology transfer to developing countries. These include financial constraints in these countries, international trade regulations, patent laws, and licensing regulations. Developing countries, thus, often opt for mature technologies which may become a source of pollution. As it turns out, the cost of environmental management is inversely proportional to the value of cheap technologies. The overall effect is that, developing countries investing in cheap technologies because of price advantage, end up increasing their environmental cost.

The Position of the North

Industrialisation and the Emission of GHGs

The Northern industry is a market-oriented enterprise aimed at creating or gaining access to markets, both objects that depend on the existence of an industrial technological base. Rosenberg and Birdzell (1986) point out that:

> "Western industry is a system for change, sometimes creating new markets and sometimes responding to them, adapting itself to changing sources of fuel and raw materials, reaching out for new technologies and sometimes creating them, and always modifying and reshaping its physical plant, which is far more transient than it appears to be".

Industrial technology development in the North, especially in heavy industries such as steel, iron and textiles, which were the bases for the Industrial Revolution, depended on energy derived from coal and applied through steam engines and steam-powered machinery.[6] Coal burning has been largely associated with the emission of greenhouse gases (GHGs), such as carbon dioxide (CO_2), which contribute towards global warming and climate change.[7]

As industrialisation continued to develop in the North, in the period 1750–1880,[8] technological innovation developed as well, creating material substitutes such as wood for coal in fabricating machinery. This diversified the energy sources for the production of final products for the market. However, this diversification of energy sources did not stabilise greenhouse gas emission. More factories were set up, and household energy consumption increased in direct proportion to population growth. The general view in the North is that, emission of GHGs has largely arisen from human activity. For example, Holdren (1992) shows the human impact, in relation to GHG emission in Table 1.

Holdren (1992), notes that:

> "Human activities exceed natural processes as mobilizers of sulphur oxides, nitrogen oxides, hydrocarbons, lead, cadmium, mercury, and suspended particulate matter in the global environment; the actions of humans have increased the global atmospheric burden of carbon dioxide by nearly 30% and that of methane by more than 100%, compared to pre-industrial levels; and among all human activities, the technologies of energy supply—above all, fossil-fuel energy technologies—are the dominant sources of most of these global pollutants and significant sources of all of them".[9]

The Northern view that a strict energy policy, of itself, would serve as a mechanism for reducing emissions of GHGs, may not fully accommodate other variables associated with the emissions. Markets created and reached by the Northern industries also need to be targeted if substantial emissions of GHGs are to be reduced.

Table 1. Energy's role in global environmental impacts

Human impact	Size of impact compared to natural processes	Energy's share of responsibility for human impact
Emission of lead into the atmosphere	1500%	65%
Spills/leaks of petroleum into the oceans	1000%	60%
Emissions of sulphur dioxide into the atmosphere	140%	85%
Accumulation of methane in the atmosphere	100%	25%
Accumulation of carbon dioxide in the atmosphere	27%	80%
Emission of particulate matter into the atmosphere	25%	45%
Emission of non-methane hydrocarbons into the atmosphere	13%	40%

Source: Holdren J. (1992) "The Energy Predicament in Perspective".

[6] Rosenberg N. and Birdzell Jr L. E. (1986) *How the West Grew Rich: The Economic Transformation of the Industrial World.* Basic Books, Inc., USA.

[7] Oeschger H. and Mintzer I. (1992) "Lessons from the Ice Cores: Rapid Climate Changes During the Last 160,000 Years". In *Confronting Climate Change: Risks, Implications and Responses* (Edited by Mintzer I.). Cambridge University Press.

[8] Rosenberg N. and Birdzell L. E. (1986) pg. 146.

[9] Holdren J. P. (1992) "The Energy Predicament in Perspective". Published in *Confronting Climate Change: Risks, Implications and Responses* (Edited by Mintzer I. M.). Cambridge University Press.

Capacity in Environmental Technology

Emissions of GHGs from normal human operations, account for the bulk of emissions worldwide.[10] These emissions are from specific, designed systems that could be modified, or re-designed so that environmental factors could be better taken into account. For example, the technical aspects of emissions from natural gas systems are well understood, and these emissions are amenable to technological solutions. Some technological innovations have devised changes that would create capacity for environmental technology. Releases of GHGs from operations other than the generation of energy would be easier to minimise; it can be done through simple procedures conducted on a daily basis, with a checklist such as the one proposed in Table 2.

In the Northern countries, capacity for environmental technology is partly influenced by juridical criteria. For example, in most of these countries, there are strict regulations controlling releases of hydrocarbons, especially for the purpose of maintaining air quality. The relevant prohibitions usually come in the form of a Clean Air Act. These countries have often instituted measures for environmental safety, and for the reduction of noise pollution. Besides such legal requirements, technical changes have led to the development of venting and gas facilities that have led to the reduction of GHGs, in certain respects.

Table 3 shows some achievements in the reduction of emissions of GHGs in the Northern countries. The technological option in this particular case was designed for the reduction of methane from oil and natural gas used in normal operations.

Table 2. Checklist for GHGs in normal operations

Gases	Process	Action
GHG	detect leakages	seal gadgets
GHG	faulty equipment	replace with new designs
GHG	production mode	rehabilitate and repair production systems
GHG	inefficient management	training, new skills, relevant knowledge, knowledge and information exchange

Table 3. Options for reducing methane emissions from oil and natural gas systems

	Methane reduction strategies			
Considerations	Reduced venting and flaring during production	Improved compressor operations	Improved leak detection and pipeline repair	Low emission technologies and practices
Reduction techniques	• Recover associated gas • Re-inject • Flare	• Reduced fuel use • Gas turbines • Reduced starts/stops	• Detection • System monitoring • Repair/replace	• Automatic shut-off valves • Low-bleed devices
Support technology	• Gas infrastructure • Re-injection well drilling • Efficient flares	• Lean burn engines		
Availability[11]	• Currently available	• Currently available	• Currently available	• Currently available
Capital requirements	• Low[12]	• Medium	• Low/Medium	• Low
Technical complexity	• Low	• Low	• Medium	• Low
Applicability	• Dependent upon current emissions technology and capital availability	• Large compressor stations	• Widely applicable – older systems – poor conditions	• Widely applicable
Methane reductions	• Up to 50%	• Up to 90%[13]	• Up to 80%	Assessment in progess

Source: US/Japan, January 1992, Working Group on Methane, *Technological Options for Reducing Methane Emissions: Background Document of the Response Strategies Working Group.*

[10] US/Japan, January 1992, Working Group on Methane, *Technological Options for Reducing Methane Emissions: Background Document of the Response Strategies Working Group.*

[11] With continuing improvements expected over the next decade.

[12] Developing a gas infrastructure for associated gas use will require a large capital investment.

[13] At individual sites or systems.

Limits of Current Technology

The table above clearly shows that the technology required for the reduction of emissions involves large capital investment. Northern countries have heavily invested in research and development (R&D). High R&D costs have compelled these countries to avail their technologies on the market at high prices which developing countries cannot afford. Because of competitive technical skills in the Northern countries, technical change has become so dynamic as to assume a characteristic of autonomy, which rarely lends itself to political controls, or to governmental exercises of supererogation vis-a-vis poor countries.[14] This state of affairs will disadvantage the poor countries, besides, for the reason that the life-span of these technologies is very short, and varies with the level and characteristics of market demand.

Governments and private corporations are finding it difficult to continuously finance, and provide incentives for technological development. This is a limiting factor in the Northern countries, as regards the facilitating of the development of technologies that would reduce emissions of GHGs.

The Position of the South

Scope of Industrialisation

Countries of the South view industrialisation as a mechanism for creating employment opportunities for an increasing labour force. They view it also as a manifestation of economic growth and development. As countries in the South anticipate being fully industrialised, for example, in the case of Malaysia by the year 2030, their energy consumption would continue to increase. This would contribute towards the accumulation of GHGs in the atmosphere. And, since these gases are responsible for climate change, it would be necessary for countries in the South to aim at industrialisation with the option of utilising environmentally-sound technologies.

But, the problems of, and prospects for industrial development in the countries of the South differ greatly in quality and magnitude. Some countries of the South have abundant natural resources and large domestic markets which offer a foundation for industrial development. There are also, smaller countries of the South, which are endowed with resources that they have made the basis for an export-oriented processing industry. Since the majority of these countries have based their industrial development on export commodities such as garments, consumer electronics, and light engineering,[15] they have to be technically competitive, a requirement which dictates that they enhance their technological base. However, such a technological base is largely lacking, as witnesses the report of the South Commission (1990):

> "The countries of the South are almost entirely buyers in the international market for technology, in which sellers enjoy an oligopolistic position".[16]

The dilemma of the countries of the South is fully recognised by the Convention on Climate Change, which recognises that:

> "all countries, especially developing countries, need access to resources required to achieve sustainable social and economic development and that, in order for developing countries to progress towards that goal, their energy consumption will need to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general, including through the application of new technologies on terms which make such an application economically and socially beneficial".[17]

Potential for the Sequestration of Carbon and for the Abatement of GHGs

The debate in the negotiations of the Climate Convention, focused mainly on the reduction of the use of coal and other related fuels that account for the large emissions of carbon dioxide and other GHGs. Estimates show that industrial processes account for emissions of up to 21.8 billion metric tons of carbon dioxide per year, or about 78% of human induced carbon dioxide emissions worldwide.[18] Countries in the North have made attempts to capture carbon dioxide from exhaust gases, from fossil-fuel combustion, and to sequester it away from the atmosphere. For example, national MARKAL[19] models have

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[14] Juma C. and Ojwang J. B. (1989) *Innovation and Sovereignty: The Patent Debate in African Development.* African Centre for Technology Studies (ACTS), Nairobi, Kenya.

[15] *Our Common Future* (1987) World Commission on Environment and Development, pg. 216.

[16] *The Challenge to the South. The Report of the South Commission*, (1990), pg. 252.

[17] United Nations Framework Convention on Climate Change (UNFCCC), Text, pg. 4.

[18] Faeth P., Cort C. and Livernash R. (1994) *Evaluating the Carbon Sequestration Benefits of Forestry Projects in Developing Countries.* World Resources Institute and Environmental Protection Agency (EPA), Washington DC, USA.

[19] MARKAL, are computing models developed by Belgium, the Netherlands, and Switzerland to evaluate national carbon dioxide emission reduction measures.
See, Bahn, O., Du Merle O., Goffin J.-L. and Vial J.-P. (1992) *A Cutting Plane Method from Analytic Centres for Stochastic Linear Programming.* Department d'Economie Commerciale et Industrielle, Universite de Geneve; Bahn O., Haurie A., Kypreos S. and Vial J.-P. *A Decomposition Approach to Multi-Regional Environmental Planning: A Numerical Study.* Department d'Economie Commerciale et Industrielle, Universite de Geneve, November 1, 1993; Goffin J.-L., Haurie A. and Vial J.-P. "Decomposition and Non-Differentiable Optimization with the Projective Aligorithm". *Management Science* 38 (1992): pp. 284–302; Goffin J.-L. and Vial J.-P. "Cutting Planes and Column Generation Techniques with the Projective Aligorithm". *Journal of Optimization Theory and Applications* 65 (3) (1989) pp. 409–29.

been used to show projections of carbon dioxide emissions for some countries in the North. The model has shown that, Sweden and Switzerland had the lowest emissions of carbon dioxide per capita in 1990. And, with the maximal use of emerging environmentally-friendly technologies, these countries will further reduce their carbon dioxide emissions by the year 2020.[20]

Countries in the South, experience severe deforestation. Faeth et al. (1994) argue that, trees contain stored carbon and when they are cut down, as is common in developing countries, at an annual rate of 17 million hectares, substantial amounts of carbon dioxide are released into the atmosphere. On average, deforestation accounts for about 6.4 billion metric tons of carbon dioxide emissions, or about 22% of global carbon dioxide emissions.[21]

The potential for the sequestration of carbon, and abatement of GHGs in the South, reflects mainly on issues related to land use and land tenure. Forests and forest soils, since they store carbon, could potentially be utilised as options for sequestering carbon in the South. It would be useful to initiate processes for development projects that target tree plantations, agroforestry schemes, better land use, and crop choices that would store additional carbon. The South also requires technologies that would protect delicate ecological zones, prevent deforestation, and continue to preserve carbon in existing forests.

In the North, concepts such as tradeable permits or allowances have been proposed, as an approach to the reduction of emissions of GHGs. In the US, for example, tradeable permits are used to control sulphur dioxide. In these schemes, permits are assigned to cover emissions, and those permits assigned but not utilised, could be sold or traded. This approach is extremely complex, in its measurement and account-keeping; and on this account it may work for the industrialised countries but not the developing countries.

Houghton and Woodwell (1994) affirm that, a total of about 8 billion metric tons (BMT) of carbon are released into the atmosphere annually, 6 BMT of this emanating from fossil fuels, and about 2 BMT from deforestation.[22] Forest management, as practised in many countries of the South, plays a role in reducing carbon emissions. Forest policies in these countries will prevent deforestation where they impose strict prohibitions on forest burning, or illegal logging, and where they provide for the protection of forest reserves through effective security arrangements. What needs to be done, is to reinforce such policies by providing for effective implementation and for better forest management. Reforestation programmes through tree planting, community forest management, and natural regeneration of vegetation will also provide potential for carbon sequestration.

Limitations to Carbon-Sequestration Capacity

The economy of the majority of the countries in the South is overwhelmingly dependent on agriculture. The role of land use in this context plays an important role in the economic survival of these countries. But, tree planting as a mechanism to sequester carbon constitutes severe limitations to the scope for expanding agricultural activities, since both activities will compete for the same land and soil. Unproductive agricultural areas will hardly be conducive to tree planting; for the imperfect conditions of soil, moisture, humidity and temperature cannot support tree planting either.

Reforestation, afforestation and agroforestry schemes for countries in the South, as means of sequestering carbon, have a limited temporal capacity; the forests, after certain limits are reached, may not be able to hold more carbon.[23] In addition, tropical trees take a long time to mature; and in that gestation period, more and more carbon will be held, but, at maturity, less and less carbon would be held. Therefore, reforestation would only absorb carbon from the atmosphere temporarily.

The Problem of Technology

If the countries of the South are to use forests effectively as a carbon-sequestration device, they would have to enhance their technical know-how, as well as their measurement and recording capabilities; they would have to accumulate more knowledge about forest-types, and about the respective sequestration capacity of these. These countries would have to improve their forest-management skills, so as to sustain the capacity of the forests as carbon sinks. Indeed it would be necessary for these countries to perfect technologies for the maintenance of wood-fuels, so that these may continue to serve as a substitute to fossil-fuels.

[20]IEA, Energy Technology Systems Analysis Programme (ETSAP), *Technological Boundaries of Future CO_2 Emissions Mapped for Nine Countries* Issue No. 2 February 1994.

[21]Faeth P., Cort C. and Livernash R. (1994) *Evaluating the Carbon Sequestration Benefits of Forestry Projects in Developing Countries.* World Resources Institute and EPA Publication, Washington DC, USA.

[22]Houghton R. A. and Woodwell G. M. "Forests as Carbon Sinks", in a report of a Workshop held 9–11 January, 1994, Southampton, Bermuda, *Criteria for Joint Implementation Under the Framework Convention on Climate Change* (Edited by Ramakrishna K.), Woods Hole Research Centre, MA, USA.

[23]Houghton R. A. and Woodwell G. M. "Forests as Carbon Sinks", The Woods Hole Research Centre, Woods Hole, Massachussets, USA. February 1992.

Improved wood technologies would enable the countries of the South to convert wood into ethanol, hydrogen or other alternative fuels, for use in industry and in the transport systems. This is an area in which suitable arrangements for technology acquisition would have been highly desirable.

It may be remarked that, the problem of technology in the South has been perceived in diverse ways. It has been noted in the climate negotiations[24] that several factors in the South create problems for technology transfer. These factors include:

- paucity of appropriate institutions and of relevant trained human resources;
- existence of certain social, cultural, moral or ethical attitudes which impede adaptation from restrictive formal approaches to technical change;
- inadequate financial resources, and a severe economic recession, which have made it prohibitive to purchase, operate and maintain new technologies; and,
- unaffordable initial capital costs in the case of alternative technologies.

Such persistent hardships place the countries of the South in a position where their only course of action is to accommodate themselves to both foreign and local technologies, with such advantages or disadvantages as these may have, putting them to the most judicious use in dealing with problems of climate change.

Equitable Exchanges: The Transfer of Environmental Technology

Given the fact that the South has only a limited technological base for addressing issues of climate change, and other related problems, it is imperative for the South to utilise existing technical development cooperation arrangements, bilateral or multilateral, to strengthen local institutional capacity. These arrangements would also contribute towards human resource development, through such arrangements as training, refresher courses, and information dissemination and exchange. Such arrangements could also serve as avenues for necessary financial assistance, especially in relation to the purchase, service and maintenance of new technologies.

This is not, of course, to overlook the ideal policy option for the developing countries, namely, to rededicate themselves to the object of identification and proper use of their domestic resources, and the skilled management of these such as would provide an enabling environment for endogenous technological capability. Enlightened policy-making, and attendant good administration, would provide the ideal conditions for achieving such a goal.

Concerns about governance at international, regional and national levels should seek to achieve greater openness, efficiency and equity in the management of resources. A general observance of good governance would, no doubt, temper the obstacles to technology transfer, moderate market behaviour and restrain the exploitative aspects of the market, moderate the more self-seeking trade practices, and provide equitable restraints to the sharp edges of the legal regimes relating to industrial property rights.[25] The social equities resulting would tend to promote the free flow of technologies from North to South.

Conclusion

The recent entry into force of the Climate Convention is testimony to the fact that the world has opted for common negotiated settlement in solving large-scale global problems such as those associated with global warming and climate change. Yet the realisation of such an option is inextricably linked to the technological dilemma which stares the south squarely in the face.

A basic responsibility rests on the South, to strive, through the institution of appropriate policies and management structures, to find a solution to the technological problem. But no-less is the burden of moral responsibility resting on the North, to assist the South to come to participate meaningfully in the quest for the agreed solution, namely the stabilisation of climate.

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[24]WMO/UNEP (1990) *Climate Change: The IPCC Response Strategies*, Intergovernmental Panel on Climate Change, Geneva, Switzerland.

[25]Lall S. (1993) "Understanding Technology Development", *Development and Change*, Vol. 24, pp. 719–53; Bell M., *Continuing Industrialization, Climate Change and International Technology Transfer*, Science Policy Research Unit, University of Sussex, December 1990.

The Unequal Use of the Global Commons

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Preamble

We take as our starting point the Intergovernmental Panel on Climate Change (IPCC) judgment in 1990 that a minimum 60% cut in global CO_2 emissions was necessary to achieve an immediate stabilisation of atmospheric CO_2 levels. Not to comply with this requirement as rapidly as practicable would: (a) take unnecessary risks with the planet's life-support systems, and (b) threaten huge numbers of people present and future *who have had no part in causing the problem.* We also note (c) the "Constant Airborne Fraction" (CAF, c. 60% of any year's CO_2 output is retained in the atmosphere—see IPCC First Assessment Report), (d) the 83% of industrial CO_2 output accumulated by the industrial countries since 1860 (see GCI "GDP: CO_2 = BAU:IOU"), (e) the global formal economy being still at least 90% dependent on energy for fossil fuel burning (see IEA), and (f) the close relationship between CO_2 and GDP globally and regionally (see Figs 1 and 2).

We next make a judgment which is both ethical and practical—and we call on other analysts working in this field to make the ethical positions and values inherent to their work as explicit as we do. In our judgment, the most valid starting point in assessing how to minimise the adverse effects of global climate change is to recognise that each human individual has an equal entitlement to such carbon usage as can safely be allowed to continue. This does not reflect the current pattern of relationships between nations, as the assessments in this paper will show. However, we believe an unprecedented degree of cooperation will be required to realise any package of policies and procedures capable of fending off a climate disaster.

Equal rights to carbon usage, and to the GDP income that derives from it, is a principle that embodies in practical terms the right to the local enjoyment of shared and interdependent global ecosystems—in the worst case the right to personal survival. We know of no other guiding principle which would command the unprecedented level of agreement now required within the international community. This agreement will be essential if a common language is to be developed which can be used to describe the problem of global climate change in terms of its socio-economic causes as well as its environmental symptoms, and address solutions on an urgent time scale.

If an approach based on this principle is not adopted, the likely scenarios for the future range from environmental blackmail and counter-blackmail, to massive and cruel economic sanctions, through the use of naked force. None of which preclude the possibility, or even the probability, of large-scale ecological dysfunction globally.

Equity is the Solution

We believe that any proposed solutions to the problems [which both cause and proceed from global climate change] which are not equitable will not work. In a very real and fundamental way, *equity is the solution*—i.e., properly valuing each other and the planet. A failure to understand and apply this is a failure to appreciate the double-jeopardy in which humanity is now situated. We face the actuality of scarce resources (sink capacity etc.) and the increasing potential for conflict with each other over these scarce resources. We do not imagine the solutions that emerge will be based exclusively on the principle of rights to equal carbon usage. However, the analytical tools that we are developing and making available are based on the principle of equal rights to carbon usage, and the results that our work will reveal can be used as a network of reference points. Anyone who wishes to diverge from or ignore the principle can then describe what they propose, and this can be judged against our results. It would then be for the international community, through a reformed and better advised negotiating process, to decide whether or not the degree of divergence proposed was socially and ecologically viable.

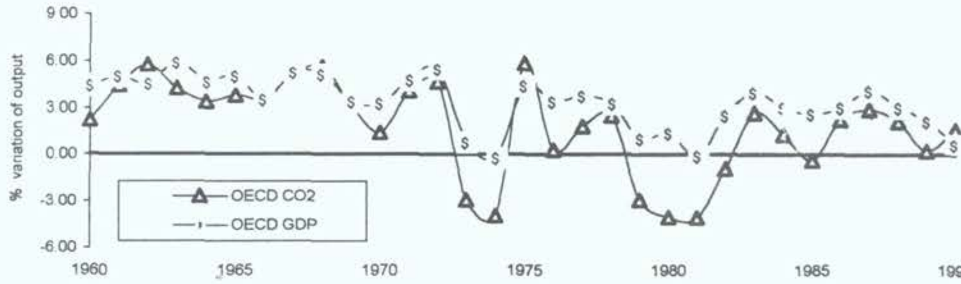

Fig. 1. OECD—Year-on-year % points GDP: Industrial CO_2, 1960–1990.

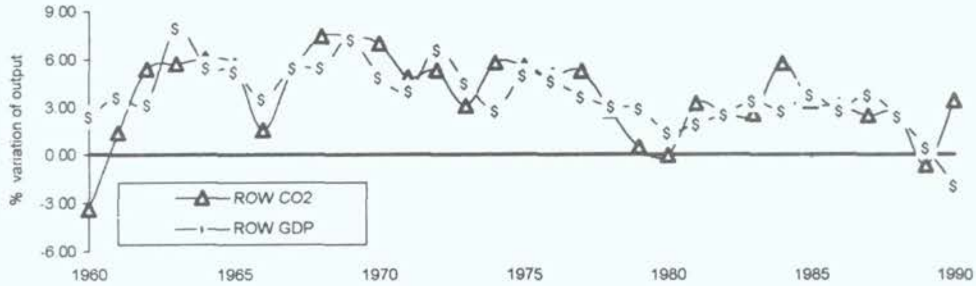

Fig. 2. Rest of the world year-on-year % points GDP: Industrial CO_2, 1960–1990.

Applying Equity

The social, financial and ecological inter-relationships of equity should guide the route to global ecological recovery. Policy Instruments such as *"Tradeable Emissions Quotas"*, *"Carbon Taxes"*, and *"Joint Implementation"* may well serve to make matters worse unless they are properly referenced to targets and time-tables for equitable emissions reductions overall. This means devising and implementing a programme for convergence at equitable and sustainable par values for consumption on a per capita basis globally. This means that rights to income are accompanied by responsibilities for the impacts associated with the generation of that income, which effectively rewards efficiency. It has always seemed of fundamental relevance to us that while the problems consequent on global climate changes will most probably affect everyone, the cause of global climate change has been the activities of a few. This is the political issue, central to global ecological recovery. The structural and restructuring implications of this are considerable, but the detail of this is beyond the scope of this paper. This paper *simply* presents a factual retrospective assessment of the relevant data ascertaining who—in the context of *"equal per capita rights"*—the *"debtors"* and *"creditors"* were, and the size and trends of their respective credits and debits.

Data Used in this Modelling

The data which we take as the starting point for the calculations presented here are all publicly available. For 189 countries and for the period 1950–1990 we used:

(a) National Population Figures: are taken from UN statistics,

(b) GDP in US Dollars (USD): at constant 1985 prices are extrapolated from the Penn World Tables 5.5 (with guidance from the PWT5 authors). Because there was a lot of conversion involved occasionally involving huge exchange rate fluctuations, for the quota calculations only, each country's USD curve was exponentially smoothed across the period. Because data was lacking for a few smaller countries for the first decade, these gaps were filled in with exponential regression. Also, because data for a few smaller countries was lacking altogether, another source of data (CHELEM-1980 constant USD) was used rebased to 1985 constant dollars.

(c) GDP in Purchasing Power Parity Dollars (PPP): at constant 1985 prices are taken from the Penn World Tables 5.5. Because data was lacking for a few smaller countries for the first decade, these gaps were also filled in with exponential regression. And, because data for a few smaller countries was also lacking altogether, another source of data (CHELEM-1980 constant PPP) was used appropriately rebased to 1985 constant dollars.

(d) Industrial CO_2 emissions: in tonnes of carbon are from Carbon Dioxide Information Analysis Centre (CDIAC). These data cover emissions from oil, coal and gas combustion and also from the manufacture of cement.

Calculations for Allocations

With the above as input data we made a series of fundamentally simple calculations, for every nation and for every year from 1950 to 1990. We emphasise that these calculations are based on freely available and uncontentious data and are simple to make. If they appear complex, it is purely because of the volume of data being handled and the use of data-management computer software to group the results in various ways and to produce a variety of graphical presentations.

In this paper we present three[1] quota regimes. The increasingly unequal consumption patterns revealed are stark. In that this represents an assessment of the existing data for the past against the stated criteria for equitable and sustainable consumption, we regard this as a factual presentation of what actually happened over the last 40 years. Some implications are drawn from this in the commentary on the quota regimes which follow and in the conclusions at the end of the paper.

Regime 1—Carbon Usage (Impact) Allocation

How it is Done and Why

This calculation allocates *"globally allowable carbon usage"* (i.e., 40% of each year's actual global usage) to each nation on the basis of their populations, and compares this allocation with their actual usage to give a *"debit"* or *"credit"* figure.

- *"Debit"* means the amount by which a nation took less than its equitable share of the carbon usage which could be safely allowed to continue in any year globally.
- *"Credit"* means the amount by which a nation took more than its equitable share of the carbon usage which could be safely allowed to continue in any year globally.
- *"Debitors"* are the total number of people in the nations which took more than their equitable share of the carbon usage than could safely be allowed to continue in any year globally.
- *"Creditors"* are the total number of people in the nations which took more less their equitable share of the carbon usage than could safely be allowed to continue in any year globally.
- *"Efficiency"* means the ratio of GDP (in USD or PPP$) to carbon from CO_2 from fossil fuel burning.

Across the period 1950–1990, we also then calculated and compared:

- the total number of *"creditors"* and *"debitors"* in each year,
- their respective gross and per capita *Incomes* in both USD and PPP$, and
- their respective gross and per capita *Impacts*, and
- their respective *Efficiency* trajectories in both USD and PPP$.

The curves for these are traced in composite graphic, Fig. 3.

Some of the Results

1. Until the early 1980s, there was a clear majority of *creditors* over *debitors* (see centre graphic Fig. 3). However, when per capita emissions in China went above the *Sustainable Equitable Global Per Capita Impact Threshold* (SEGPCIMT) in 1982, the country switched from being an *"Impact creditor"* to being an *"Impact Debitor"*. This explains why the relative numbers of *debitors* and *creditors* changed in this quota regime.
2. The *gross* combined ***Impacts*** (see middle graphic left hand column, Fig. 3) of *debitors* and *creditors* rose at over 2% per annum across the period split approximately 10:1 between *debitors* and *creditors* throughout.
3. The average *per capita* ***Impacts*** (see middle graphic right hand column Fig. 3) of *debitors* and *creditors* rose across the period until 1982, split approximately 10:1 throughout. China crossing SEGPCIMT caused both averages to fall thereafter. The average *per capita* ***Impact*** of the creditors was never more than half SEGPCIMT.
4. The *gross* combined USD ***Income*** (see graphic top left hand corner Fig. 3) values of the *debitors* and the *creditors* rose across the period and was split at more than 10:1 throughout.
5. The average *per capita* USD ***Income*** (see graphic top right hand corner Fig. 3) of *creditors* rose across the period until the early 1980s. The average *per capita* USD ***Income*** of *creditors* remained constant across the period overall and was never more than half the value of *"Sustainably derived income"* (SDI—explained in regime 2). The split between *creditors* and *debitors* was on average 10:1 throughout.
6. The average USD ***Efficiency*** of *creditors* and *debitors*, initially favouring *creditors*, converged over the period, with the global average rising slightly towards the end of the

[1]Of five—please apply to GCI for full version with detailed country by country analysis if desired. GCI's data-management and modelling software is also available on application.

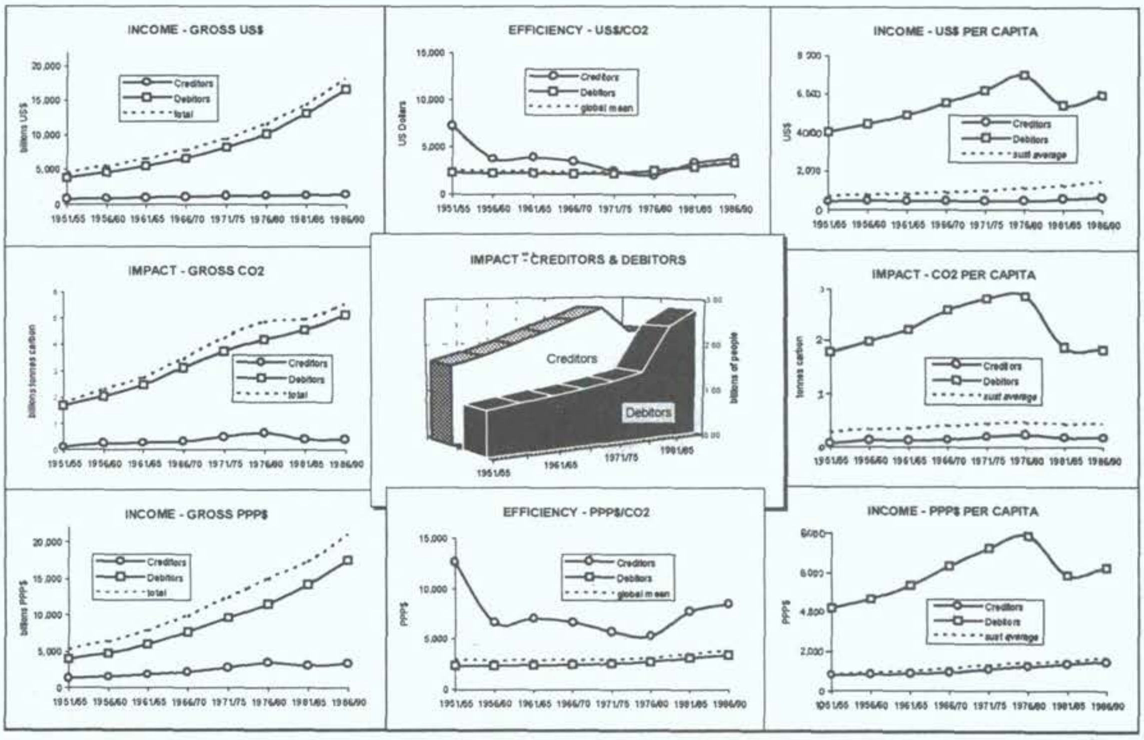

Fig. 3. Impact quotas—Creditors' and Debitors' relative ***Incomes, Impacts and Efficiencies***, in US$ and PPP$, 1950–1990.

period (see centre graphic top row Fig. 3).

7. The *gross* combined PPP ***Income*** values of the *debitors* and *creditors* rose on average across the period and was split at less than 10:1 throughout (see graphic bottom left hand corner Fig. 3).
8. The average *per capita* PPP ***Income*** (see graphic, Fig. 3) of *debitors* rose across the period until the early 1980s. The influence of China crossing SEGPCIMT caused the average to fall thereafter. The average *per capita* PPP *Income* of *creditors* rose across the period overall at the value of *"sustainably derived income"* (SDI). The differential split between *creditors* and *debitors* was roughly 10:1 until the early eighties at which time the *debitor* average fell causing temporary convergence.
9. The average PPP ***Efficiency*** (see centre graphic bottom row Fig. 3) of *creditors* and *debitors*, was always higher with the *creditors*, but converged over the period until the early 1980s. The global average rose slightly throughout the period with *debitors* always below this average.

The combined picture shows that the *debitors'* high *per capita* ***Income*** goes with high *per capita* ***Impact*** at low ***Efficiency*** values and that the *creditors'* low *per capita* ***Income*** goes with low *per capita* ***Impact*** at high ***Efficiency*** values. This is the basis of GCI's contention that—in the context of *"understanding and responding to the unequal use of the global commons"*—debitors live unsustainably and creditors live sustainably. Debitors do this by over-consuming global climate resources, both at the expense of and subsidised by, creditors who do the opposite. In GCI's view the "credit" in any of these quota regimes represents a subsidy from the *"creditors"* to the *"debitors"*.

Across the period 1950–1990 we also calculated and compared the curves traced in Fig. 4.

- The global total credit/debit curves for ***CO_2-Impact,*** and
- The credit/debit curves of the OECD countries and the Rest of the World (ROW).

Had creditors assessed their full equitable share across the period, the debit curve would have been deeper by the amount registered as credit. It is this credit amount which represents the subsidy from the creditors to the debitors.

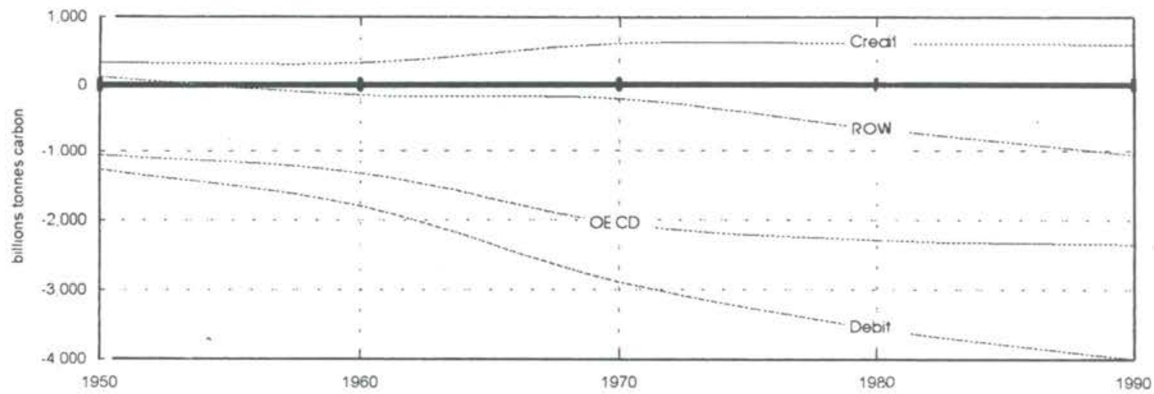

Fig. 4. OECD and Rest of the World (ROW) compared to total CO_2 impact credit/debit.

Regime 2—US$ Income Allocation (Based on Global Efficiency)

How it is Done and Why

This calculation converts each nation's allowable carbon usage into a *"sustainably derived income"* (SDI), on the basis of the global annual average figure for the efficiency of carbon usage (i.e., units of GDP produced on an average per unit of CO_2 emitted). This allocation is then compared with each nation's actual income (GDP) to give a *"debit"* or *"credit"* figure.

- *Debit* in this case means in any year the amount by which a nation exceeded its equitable share of SDI globally.
- *Credit* in this case means in any year the amount by which a nation fell short of its equitable share of SDI globally.
- *"Debitor"* means in any year the total number of people in the nations which took more than their equitable share of SDI globally.
- *"Creditor"* means in any year the total number of people in the nations which took less than their equitable share of SDI globally.

Because this calculation is based on the global average efficiency of carbon usage, nations capable of burning carbon at an average efficiency greater than the global average *"lose out"* on sustainably derived income under this system. This point is addressed in the PPP$ efficiency regime which follows.

Across the period 1950–1990, we also then calculated and compared:

- the total number of *"creditors"* and *"debitors"* in each year,
- their respective gross and per capita ***Impacts,***
- their respective gross and per capita ***Incomes*** in both USD and PPP, and
- their respective ***Efficiency*** trajectories in both USD and PPP.

The curves for these are traced in the composite graphic, Fig. 5.

Some of the Results

1. There was an increasing majority of ***USD Income*** *creditors* over *debitors*, reaching 2:1 by 1990.
2. The *gross* combined ***CO_2 Impact (USD)*** (see middle graphic in the left hand column Fig. 5) of *debitors* and *creditors* rose at over 2% per annum split approximately 10:1 overall.
3. The average *per capita* ***Impacts*** (see middle graphic in right hand column Fig. 5) of *debitors* and *creditors* rose throughout the period split on average 10:1 throughout. The average *per capita* ***Impact*** of the *creditors* was decreasingly less than SEGCIMT.
4. The *gross* combined USD ***Income*** (see graphic in top left hand corner Fig. 5) of the *debitors* and the *creditors* rose across the period split at increasingly more than 10:1 throughout.
5. The average *per capita* USD ***Income*** (see graphic top right hand corner Fig. 5) of *debitors* rose across the entire period. The average *per capita* USD ***Income*** of *creditors* remained constant overall at increasingly less than half the value of *"sustainably derived income"* (SDI). The maldistribution between *creditors'* and *debitors'* ***Income*** seriously increased throughout.
6. The average USD ***Efficiency*** (see top graphic in middle column Fig. 5) of *creditors* and *debitors*, initially favouring *creditors*, reversed over the period, with *debitors* following the slightly rising global average towards the end of the period and *creditors* declining below the global average.
7. The *gross* combined PPP ***Income*** (see graphic in bottom left hand corner Fig. 5) values of the *debitors* and the *creditors* rose on the average and the less than 10:1 initial split continued throughout.
8. The average *per capita* ***PPP Income*** (see graphic bottom right hand corner Fig. 5) of *debitors* rose while the average *per capita*

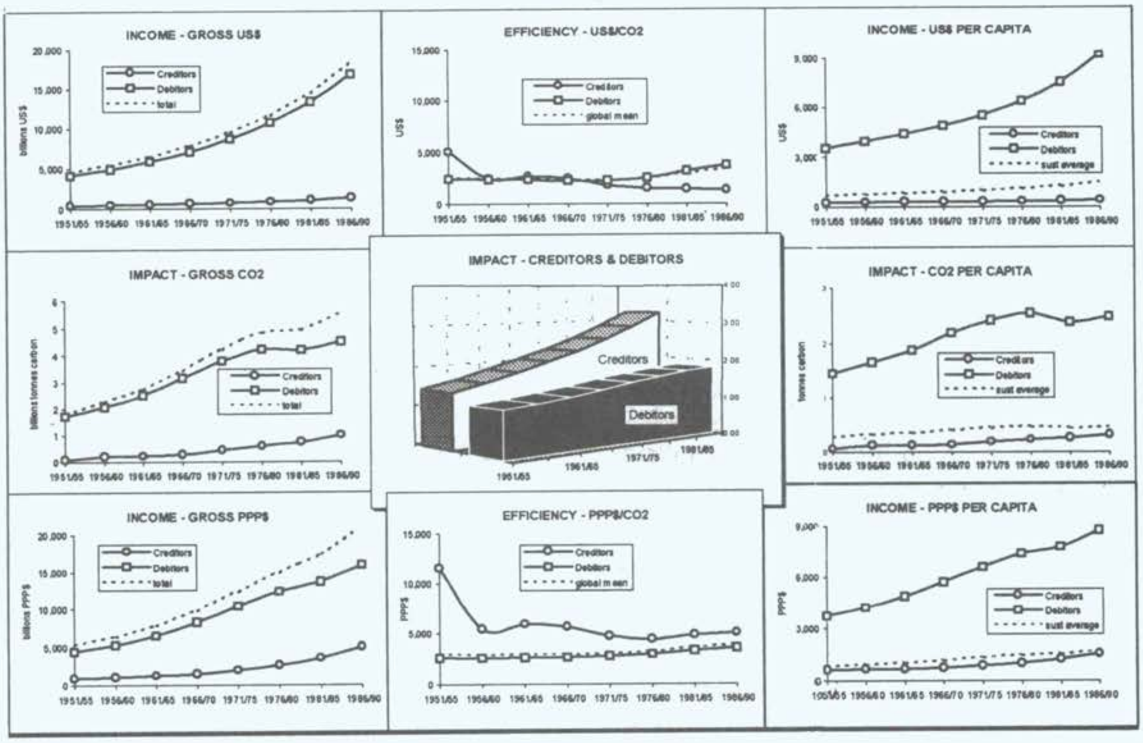

Fig. 5. USD income quotas—Creditors' and Debitors' relative ***Incomes, Impacts and Efficiencies,*** in US$ and PPP$, 1950–1990.

PPP ***Income*** of *creditors* rose only to the threshold value of SDI. The split between *creditors'* and *debitors'* income was less than 10:1.

9. The average PPP ***Efficiency*** (see bottom graphic in the middle column Fig. 5) of *creditors* was always higher than the *debitors*. The global average rose slightly throughout the period with *debitors* always just below this average.

The combined picture—at least in PPP$—shows that the debitors' high *per capita* ***Income*** with high *per capita* ***Impact*** at low ***Efficiency*** values and that the creditors' low *per capita* ***Income*** goes with low *per capita* ***Impact*** at high ***Efficiency*** values. The most striking point about this regime is that by the end of the period, two-thirds of the global population are creditors sharing 6% of global USD GDP, whilst the other one third are debitors sharing 94% of global USD GDP. It is in this context that *"CO_2 emissions trading"* and *"Joint Implementation"* have been proposed in the name of *"cost-effectiveness"*. However, while the US dollar remains the dominant currency in the enforced "global" market, the adverse systemic influence of this increasing maldistribution of global purchasing power and globally unequal consumption patterns would appear to invite conflict rather than the co-operation required by the suggested trading arrangements. Moreover, it cannot be plausibly argued in the context of ecological economics that such trade will be "cost-effective". In cash terms, the magnitude of the existing debit outweighs the available credit by a factor of 4:1. A failure to re-establish ecological credit proportional to this overhang, simply commits the global system to a process of adapting to increasing risks and rising costs. As such, "cost-effective" (as used by the economists) in reality means *not* "***benefit***-effective", i.e., it is *not* delivering "global benefit", it is delivering increased global cost or disbenefit (violating the requirements of the climate convention).

Across the period 1950–1990 we also calculated and compared the curves and traced in Fig. 6.

- the global total credit/debit curves for ***USD Income,*** and
- the credit/debit curves of the OECD countries and the Rest of the World (ROW).

OECD countries, with 19% of global population, were responsible for 99% of the accumulated ***USD Income*** debit.

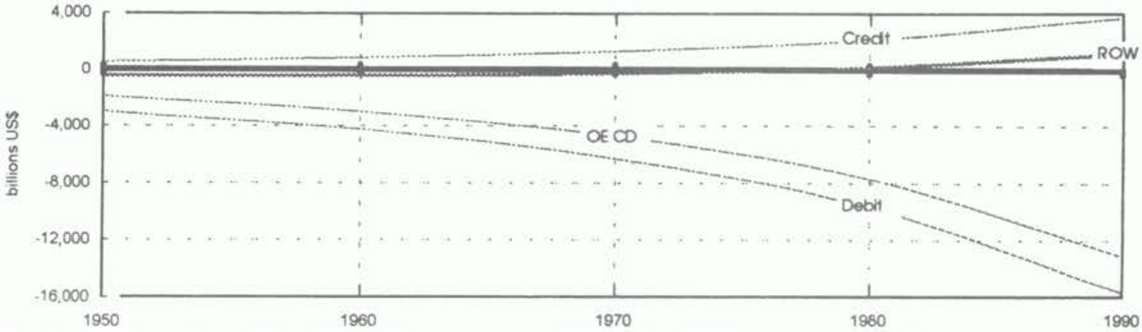

Fig. 6. OECD and Rest of the World (ROW) compared with total US$ income credit/debit.

Regime 3—PPP$ Income Allocation (Based on National Efficiency)

How it is Done and Why

This calculation shows income (GDP) data expressed in *"Purchasing Power Parity"* (PPP) dollars. PPP$ delink national currencies from their US$ exchange rates, and value them instead for domestic purchasing power.

This calculation converts each nation's allowable carbon usage into a sustainably derived income (SDI), on the basis of the *national* (not global) figure for the efficiency of carbon usage (i.e., units of GDP produced on an average per unit of CO_2 emitted). This allocation is then compared with each nation's actual income (GDP) to give a *"debit"* or *"credit"* figure.

Because this calculation is based on the *national* efficiency averages of carbon usage, nations currently burning carbon at an average efficiency greater or less than the global average are respectively rewarded or penalised. The league table of countries is different from the league table arising out of the earlier impact and US$:$CO_2$ income allocation regime (compare columns 1, 2 and 3 on pages 190–193).

Across the period 1950–1990, we also then calculated and compared:

- the total number of *"creditors"* and *"debitors"* in each year,
- their respective gross and per capita ***Impacts,***
- their respective gross and per capita ***Incomes,*** in both USD and PPP, and
- their respective ***Efficiency*** trajectories in both USD and PPP.

The curves for these are traced in the composite graphic, Fig. 7.

Some of the Results

1. As with the ***Impact*** until the early 1980s, there was a 2:1 majority of *creditors* over *debitors* (see centre graphic Fig. 7). However, the reference to the comparative country rankings (see Table), it will be seen that the order of countries in the league tables varies considerably between these three allocation regimes.
2. As before, the *gross* combined ***Impact*** (see middle graphic in left hand column Fig. 7) of *debitors* and *creditors* rose at over 2% per annum across the period. The initial differential was approximately 10:1 and this split increased over the period.
3. The average *per capita* ***Impacts*** (see middle graphic in right hand column Fig. 7) of *debitors* and *creditors* rose throughout the period until about 1980 and was split approximately 10:1 throughout. Thereafter both these averages fell. At the end of the period the average *per capita* ***Impact*** of the *creditors* was decreasingly less than half the value of SEGCIMT.
4. The *gross* combined USD ***Income*** (see graphic in top left hand corner Fig. 7) of the *debitors* and the *creditors* rose across the period and was split at increasingly more than 10:1 throughout.
5. The average *per capita* USD ***Income*** (see graphic in top right hand corner Fig. 7) of *debitors* rose across the period until the early 1980s. The average *per capita* USD ***Income*** of *creditors* remained constant at less than half the value of SDI. The split between *creditors'* and *debitors'* ***Income*** widened overall.
6. The average USD ***Efficiency*** (see top graphic in middle column Fig. 7) of *creditors* and *debitors*, initially favouring *creditors*, reversed over the period, with *debitors* following the slightly rising global average and *creditors* recovering slightly towards the end of the period.
7. The *gross* combined PPP ***Income*** (see graphic in bottom left hand corner Fig. 7) of the *debitors* and the *creditors* rose on average for most of the period. But the initial split widened throughout.

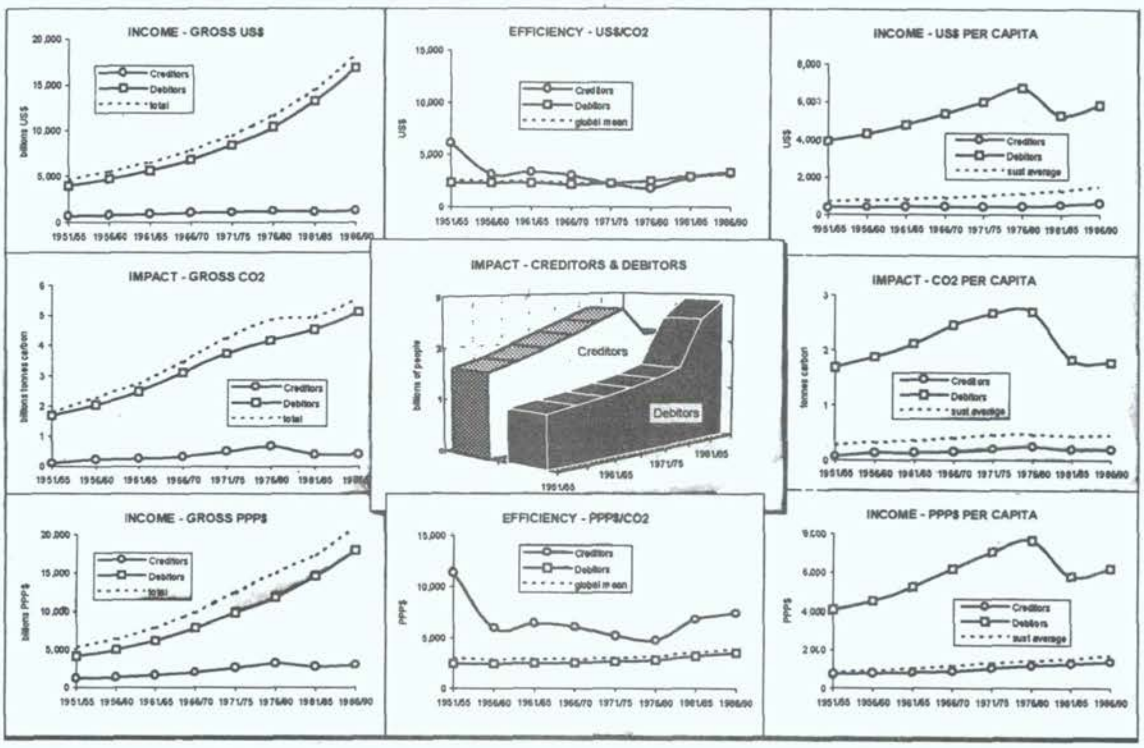

Fig.7. PPP efficiency quotas—Creditors' and Debitors' relative ***Incomes, Impacts and Efficiencies,*** in US$ and PPP$, 1950–1990.

	Impact Debit/ors and credit/ors CO_2—millions tonnes carbon		USD Income Debit/ors and credit/ors Income—billions USD		PPP Efficiency Debit/ors and credit/ors Efficiency—billions PPP		
1	USA	39,495	USA	102,440	USA	102,272	1
2	USSR	22,672	USSR	37,978	USSR	30,178	2
3	Germany	8,996	Japan	29,468	Japan	24,385	3
4	UK	5,700	Germany	19,002	Germany	19,518	4
5	Japan	5,056	France	16,296	UK	16,497	5
6	France	3,233	UK	13,755	France	15,021	6
7	Canada	3,078	Italy	11,267	Italy	11,103	7
8	Poland	2,879	Canada	9,179	Canada	8,941	8
9	Italy	1,866	Australia	4,543	Australia	4,921	9
10	Czechoslovakia	1,781	Spain	4,156	Spain	4,740	10
11	South Africa	1,459	Netherlands	3,806	Mexico	4,305	11
12	Australia	1,423	Sweden	3,357	Poland	4,028	12
13	Belgium	1,039	Switzerland	2,796	Netherlands	3,885	13
14	Romania	1,033	Belgium	2,703	Saudi Arabia	3,289	14
15	Netherlands	979	Brazil	2,504	Venezuela	3,114	15
16	Spain	787	Saudi Arabia	2,463	Belgium	2,874	16
17	Mexico	768	Mexico	2,176	Sweden	2,681	17
18	Bulgaria	592	Romania	1,974	South Africa	2,255	18
19	Sweden	558	Argentina	1,892	Taiwan	2,209	19
20	Hungary	531	Austria	1,811	Switzerland	2,194	20
21	Iran	462	Denmark	1,756	Czechoslovakia	2,130	21
22	Argentina	457	Venezuela	1,740	Argentina	2,072	22
23	Yugoslavia	450	Iran	1,642	Romania	2,029	23
24	Denmark	443	Norway	1,513	Austria	1,779	24
25	Austria	370	Finland	1,436	Yugoslavia	1,734	25

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	Impact Debit/ors and credit/ors CO_2—millions tonnes carbon		USD Income Debit/ors and credit/ors Income—billions USD		PPP Efficiency Debit/ors and credit/ors Efficiency—billions PPP		
26	Korea	307	Albania	1,323	Denmark	1,593	26
27	Finland	296	Yugoslavia	1,115	Hungary	1,259	27
28	Switzerland	254	Poland	1,096	Finland	1,241	28
29	Norway	215	South Africa	1,045	Iran	1,234	29
30	Greece	200	United Arab Emirates	819	Norway	1,127	30
31	Kuwait	193	Czechoslovakia	794	Bulgaria	892	31
32	United Arab Emirates	190	Greece	786	New Zealand	798	32
33	Ireland	157	Libya	719	Greece	784	33
34	Singapore	143	New Zealand	697	Korea	758	34
35	Libya	135	Taiwan	688	Israel	550	35
36	New Zealand	129	Israel	635	Iraq	536	36
37	Israel	126	Kuwait	600	Kuwait	512	37
38	Luxembourg	115	Iraq	542	Ireland	504	38
39	Iraq	115	Hong Kong	538	Myanmar	470	39
40	Netherlands Antilles	111	Algeria	499	Hong Kong	414	40
41	Cuba	98	Puerto Rico	490	Puerto Rico	406	41
42	Puerto Rico	89	Korea	473	Chile	404	42
43	Trinidad and Tobago	86	Ireland	427	Libya	352	43
44	Qatar	77	Portugal	371	Malaysia	322	44
45	Chile	72	Chile	361	Singapore	320	45
46	Malaysia	60	Hungary	285	Portugal	303	46
47	US Virgin Islands	48	Bulgaria	277	Cuba	277	47
48	Portugal	47	Singapore	271	Trinidad and Tobago	237	48
49	Bahrain	44	Oman	268	Yemen, AR	209	49
50	Hong Kong	44	Turkey	240	Qatar	166	50
51	Algeria	36	Malaysia	207	Luxembourg	137	51
52	Brunei	31	Qatar	186	Bahrain	110	52
53	Oman	27	Uruguay	118	Lebanon	77	53
54	Bahamas	26	Colombia	117	Brunei	61	54
55	Mongolia	21	Luxembourg	116	Iceland	57	55
56	Gabon	19	Bahrain	101	Cyprus	52	56
57	Jamaica	18	Trinidad and Tobago	100	Central African Rep.	52	57
58	Lebanon	15	Lebanon	90	Bahamas	49	58
59	Albania	14	Iceland	84	Uruguay	48	59
60	Syria	14	Peru	83	Guadeloupe	46	60
61	New Caledonia	13	Cuba	80	Netherlands Antilles	41	61
62	Iceland	13	Gabon	64	Jamaica	36	62
63	Turkey	13	Brunei	61	New Caledonia	30	63
64	Cyprus	12	Syria	51	Gabon	30	64
65	Guam	10	Panama	48	Suriname	22	65
66	Suriname	9	Cyprus	46	US Virgin Islands	19	66
67	Uruguay	7	Bahamas	46	Bermuda	16	67
68	Greenland	3	Martinique	41	Mongolia	16	68
69	Malta	3	Costa Rica	39	Malta	15	69
70	Bermuda	3	Netherlands Antilles	39	St Helena	9	70
71	Martinique	2	Jamaica	38	Martinique	9	71
72	Antigua and Barbuda	2	Reunion	37	St Vincent and Gr.	7	72
73	Panama	2	New Caledonia	35	Barbados	6	73
74	Barbados	1	Guadeloupe	33	French Polynesia	5	74
75	Western Sahara	1	Mongolia	29	Western Samoa	4	75
76	Guyana	1	Barbados	18	French Guiana	4	76
77	French Guiana	1	Bermuda	18	Antigua and Barbuda	3	77
78	Falkland Islands	1	Malta	17	Gibraltar	1	78
79	Nauru	1	Suriname	14	Seychelles	1	79
80	Cayman Islands	1	Fiji	7	Guyana	0	80
81	Christmas Island	1	Mauritius	5	Panama	0	81

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	Impact Debit/ors and credit/ors CO_2—millions tonnes carbon		USD Income Debit/ors and credit/ors Income—billions USD		PPP Efficiency Debit/ors and credit/ors Efficiency—billions PPP		
82	French Polynesia	0	Western Sahara	5	Albania	–	82
83	Leeward Islands	0	Gibraltar	5	Br. Virgin Islands	–	83
84	St Pierre and Miquelon	0	Western Samoa	4	Cambodia	–	84
85	Br. Virgin Islands	0	Tunisia	3	Cayman Islands	–	85
86	Western Samoa	0	Dominica	2	Christmas Island	–	86
87	Gibraltar	0	Antigua and Barbuda	2	Cook Islands	–	87
88	Korea, DPR	–	Seychelles	1	Falkland Islands	–	88
89	St Helena	–	Belize	1	Faroe Islands	–	89
90	Montserrat	0	St Lucia	1	Greenland	–	90
91	Niue	0.1	Christmas Island	0	Guam	–	91
92	Seychelles	0.3	Korea, DPR	0	Korea, DPR	–	92
93	Kiribati	0.6	Leeward Islands	0	Leeward Islands	–	93
94	St Kitts Nevis Anguilla	0.6	St Helena	0	Macau	–	94
95	Belize	0.6	St Vincent and Gr.	0	Montserrat	–	95
96	Faroe Islands	0.6	Niue	0	Nauru	–	96
97	Dominica	0.9	St Pierre and Miquelon	0	Niue	–	97
98	Sao Tome and Principe	1	Nauru	0	St Pierre and Miquelon	–	98
99	Grenada	1	Grenada	0	Viet Nam	–	99
100	St Lucia	1	Br. Virgin Islands	0	Western Sahara	–	100
101	Tonga	1	Montserrat	0	Yemen, PDR	–	101
102	Vanautu	1	St Kitts Nevis Anguilla	0	Sao Tome and Principe	2	102
103	St. Vincent and Gr.	1	Kiribati	-1	St Kitts Nevis Anguilla	3	103
104	Maldives	2	Falkland Islands	-1	Kiribati	5	104
105	Solomon Islands	2	Cayman Islands	-1	Belize	7	105
106	Macau	2	Djibouti	-1	St Lucia	8	106
107	Djibouti	3	Vanuatu	-1	Maldives	8	107
108	Reunion	3	Faroe Islands	-2	Grenada	8	108
109	Cook Islands	3	Greenland	-2	Tonga	9	109
110	Cape Verde	4	Tonga	-2	Vanuatu	11	110
111	Jordan	4	Sao Tome and Principe	-2	Zimbabwe	16	111
112	Equatorial Guinea	4	Swaziland	-2	Dominica	22	112
113	Fiji	4	French Guinea	-2	Solomon Islands	25	113
114	Swaziland	4	Solomon Islands	-2	Djibouti	29	114
115	Zimbabwe	4	Nicaragua	-3	Botswana	40	115
116	Comoros	5	US Virgin Islands	-4	Reunion	41	116
117	Guadeloupe	5	Guam	-4	Swaziland	44	117
118	Botswana	6	Maldives	-4	Cape Verde	54	118
119	Gambia	7	French Polynesia	-5	Fiji	57	119
120	Mauritius	8	Congo	-5	Comoros	74	120
121	Guinea Bissau	9	Cape Verde	-6	Colombia	76	121
122	Colombia	12	Guyana	-6	Jordan	76	122
123	Congo	12	Jordan	-6	Gambia	99	123
124	Costa Rica	12	Equatorial Guinea	-6	Guinea Bissau	119	124
125	Mauritania	15	Paraguay	-7	Algeria	130	125
126	Bhutan	16	Comoros	-8	Syria	139	126
127	Liberia	19	Cook Islands	-9	Costa Rica	174	127
128	Nicaragua	20	Dominican Republic	-10	Congo	179	128
129	Ecuador	25	Botswana	-10	Mauritius	183	129
130	Tunisia	25	Guatemala	-12	Turkey	185	130
131	Central African Rep.	28	Ecuador	-14	Tunisia	213	131
132	Yemen, PDR	28	Macau	-15	Zambia	227	132
133	Dominican Republic	30	Gambia	-15	Nicaragua	233	133
134	Togo	30	Guinea Bissau	-18	Liberia	239	134
135	Paraguay	31	Mauritania	-30	Dominican Republic	302	135

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	Impact Debit/ors and credit/ors CO_2—millions tonnes carbon		USD Income Debit/ors and credit/ors Income—billions USD		PPP Efficiency Debit/ors and credit/ors Efficiency—billions PPP		
136	Honduras	33	El Salvador	-31	Bhutan	330	136
137	Papua New Guinea	35	Liberia	-35	Honduras	361	137
138	Zambia	38	Bhutan	-39	Ecuador	382	138
139	Sierra Leone	38	Honduras	-41	Mauritania	417	139
140	El Salvador	42	Papua New Guinea	-46	Bolivia	509	140
141	Benin	43	Côte d'Ivoire	-47	Guinea	514	141
142	Lao PDR	44	Central African Rep.	-50	Peru	515	142
143	Bolivia	46	Bolivia	-54	Togo	544	143
144	Senegal	58	Yemen, PDR	-55	El Salvador	652	144
145	Chad	59	Togo	-57	Côte d'Ivoire	732	145
146	Guinea	61	Lao PDR	-67	Paraguay	769	146
147	Peru	61	Zimbabwe	-76	Sierra Leone	858	147
148	Guatemala	63	Sierra Leone	-78	Angola	880	148
149	Haiti	64	Benin	-81	Papua New Guinea	988	149
150	Niger	65	Senegal	-81	Egypt	1,025	150
151	Côte d'Ivoire	68	Zambia	-86	Guatemala	1,076	151
152	Angola	69	Guinea	-101	Senegal	1,171	152
153	Somalia	71	Ghana	-103	Malawi	1,416	153
154	Malawi	72	Cameroon	-107	Morocco	1,460	154
155	Mali	86	Niger	-107	Benin	1,554	155
156	Cameroon	89	Chad	-126	Ghana	1,616	156
157	Burkina Faso	99	Haiti	-128	Equatorial Guinea	1,822	157
158	Cambodia	99	Somalia	-148	Kenya	1,870	158
159	Yemen, AR	102	Angola	-149	United Arab Emirates	2,166	159
160	Madagascar	109	Malawi	-167	Haiti	2,202	160
161	Rwanda	113	Morocco	-172	Oman	2,288	161
162	Burundi	120	Mali	-189	Cameroon	2,396	162
163	Ghana	122	Yemen, AR	-189	Chad	2,580	163
164	Mozambique	126	Madagascar	-196	Mozambique	3,002	164
165	Saudi Arabia	129	Burkina Faso	-207	Niger	3,109	165
166	Morocco	152	Cambodia	-258	Mali	3,392	166
167	Sri Lanka	166	Rwanda	-269	Tanzania	3,459	167
168	Kenya	169	Burundi	-288	Madagascar	3,810	168
169	Uganda	176	Sri Lanka	-296	Philippines	3,823	169
170	Venezuela	182	Mozambique	-300	Brazil	3,902	170
171	Nepal	192	Uganda	-362	Somalia	3,940	171
172	Egypt	197	Kenya	-371	Zaire	4,044	172
173	Afghanistan	204	Zaire	-391	Sri Lanka	4,123	173
174	Taiwan	214	Sudan	-394	Burkina Faso	4,213	174
175	Sudan	221	Afghanistan	-424	Lao PDR	5,100	175
176	Tanzania	222	Nepal	-425	Thailand	5,146	176
177	Ethiopia	251	Tanzania	-489	Sudan	5,554	177
178	Zaire	301	Ethiopia	-512	Nigeria	6,967	178
179	Thailand	331	Thailand	-593	Burundi	7,827	179
180	Philippines	377	Philippines	-642	Uganda	7,845	180
181	Brazil	384	Egypt	-716	Pakistan	8,508	181
182	Myanmar	457	Myanmar	-922	Afghanistan	9,321	182
183	Viet Nam	530	Nigeria	-1,048	Rwanda	9,348	183
184	Nigeria	639	Viet Nam	-1,829	Ethiopia	9,579	184
185	Pakistan	826	Pakistan	-2,036	Indonesia	12,016	185
186	Bangladesh	1,117	Bangladesh	-2,513	China	12,782	186
187	Indonesia	1,352	Indonesia	-3,337	Nepal	27,958	187
188	China	2,331	India	-17,030	India	40,635	188
189	India	6,161	China	-25,044	Bangladesh	63,145	189

8. The average *per capita* PPP ***Income*** (see graphic bottom right hand corner Fig. 7) of *debitors* rose until the 1980s at which point it fell as the number of debitors increased. The average *per capita* PPP ***Income*** of *creditors'* rose across the period at the SDI threshold value. The differential split between *creditors'* and *debitors'* ***Income*** diverged overall with temporary convergence towards the end.
9. The average PPP ***Efficiency*** (see bottom graphic in middle column Fig. 7) of *creditors* and *debitors*, was always higher with the *creditors*, but converged and then diverged over the period. The global average rose slightly throughout the period with *debitors* always slightly below this average.

The combined picture shows that the *debitors'* high *per capita* ***Income*** goes with high *per capita* ***Impact*** at low ***Efficiency*** values and that the *creditors'* low *per capita* ***Income*** goes with low *per capita* ***Impact*** at high ***Efficiency*** values. The point about this quota regime is that using the domestic purchasing power (PPP$) of the countries is a more realistic way of measuring their relative wealth and their provision of global benefit or disbenefit. Using PPP$ from the outset of the calculations is a more realistic way of measuring their relative socio-ecological efficiencies (PPP$:$CO_2$) and it is these efficiencies which should be rewarded.

Across the period 1950–1990 we also calculated and compared the curves in the graphic below:

- the global total credit/debit curves for ***PPP$ Efficiency,*** and
- the credit/debit curves of the OECD countries and the Rest of the World (ROW).

OECD countries, representing 19% of global population, were responsible for 1635% of accumulated ***USD Income*** debit. The ROW provided an accumulated 1735% of accumulated credit.

Conclusion

These allocation exercises show the worsening maldistribution of resources globally since the war. The trend was increasingly inequitable and unsustainable. OECD countries—although they do not yet admit to it officially—are now on the defensive about this state of affairs. Their principle tactic has been to "blame developing countries for future impacts" rather than accept responsibility for the past and present impacts of the industrial countries. No-one is advocating hair-shirt politics. However, it is unrealistic for the industrial countries to promote the future as an extension of the present unless this includes a willingness to become accountable over the massive structural advantage which they have developed globally whilst running up this global environmental debt on everyone's account.

Overall, this is not a complicated debate. The resources in question are global common property and vital to survival. The well-being of all people now and into the future depend on the integrity of these resources being maintained. There is a simple choice to be made: Either we *accept* that everyone has an equal right to be here and to share the benefits of these resources or we *reject* that everyone has equal rights in this. This is choosing for equity and survival or for increasing inequity and loss of sustainability. It is that simple. As a matter of principle and of prudence, GCI accepts and affirms that everyone has an equal right to be here. We base our modelling and analysis on that acceptance, and present our analysis as an affirmation of that right. We note that rights to income should be accompanied by responsibilities for its impacts which effectively rewards efficiencies. Contrarily, the Global Cost/Benefit Analysts (now in the IPCC Working Group Three (WG III)) do not affirm the equal right to be here. They appear not even to accept it either. Certainly—at least by default—they are rejecting

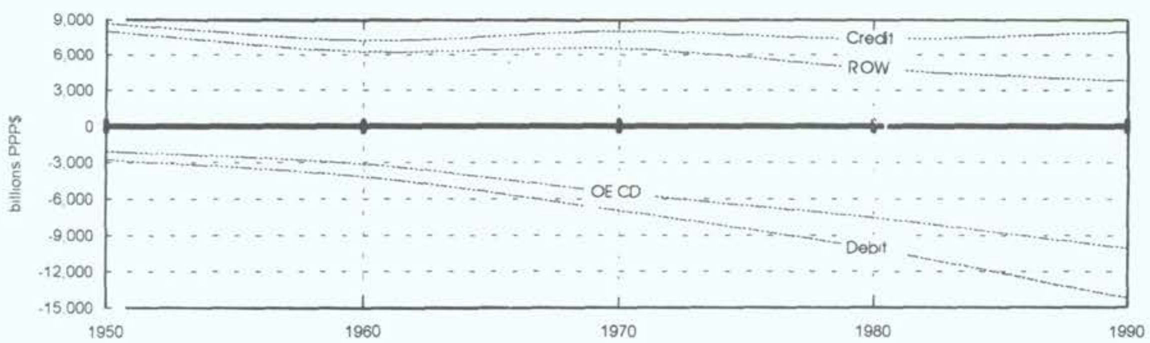

Fig. 8. OECD and Rest of the World (ROW) compared to total PPP$ efficiency credit/debit.

this right, as the analysis presented by them so far, suggests that rights increase proportional to income. Advised by these very people, the World Bank has openly promoted the idea that the right to emit carbon dioxide should be proportional to income for example.[2] The policy measures for the mitigation of emissions proposed by many of these economists preparing material for WG III[3] are based on this formula of *"rights-by-income"*. Mitigating emissions is presented by these analysts as a *cost*, and the "damages-avoided" by mitigating emissions are presented by them as the *benefit*. As intended, it sounds innocent. But it is conceptually skewed, factually inaccurate and politically devious. In reality it is a velvet glove for the iron fisted insistence on business-as-usual. At worst it is the economics of genocide. Faced with this fist, we should recognise how its grip is exerted: The exercise fundamentally depends on the analysts converting all the costs and all the benefits associated with climate changes to *cash values*. One immediate example of this is the need to give cash values to the human lives which are going to be lost (a "damage cost"). In their analysis, if the overall damage costs are calculated as high (and higher than the cost of mitigating emissions), this makes the cost of mitigation bearable, and wins the case for mitigating the emissions. If, on the other hand, the damage costs are low (and below the costs of mitigating emissions), the case has been made for business-as-usual, and the damage costs (including loss of life) become bearable. Clearly the damage cost (cash valuation) that is put on a human life is crucial.

The key question which now also arises is this: Are all human lives *equally* valuable or not? Moreover, should economists employed by the nations responsible for causing the problems of climate change, have the job of valuing the lives which are going to be lost? And even more to the point, should they value the lives of the people who are not responsible for creating the climate changes, as less valuable than the lives of those responsible? Surely we all have a fundamentally equal right to be here: Surely each person is equally valuable in this fundamental way? So far the global cost/benefit analysts say no, this is not the case. Take for example the (UK-government-funded) *Centre for the Social and Economic Research of the Global Environment* (C-SERGE) based in the UK. David Pearce is one of its directors and he is also the IPCC's convening lead author on "Social Costs". C-SERGE has already published a valuation of the lives to be lost. In a recent research paper it stated that the cash value of a "statistical life" in the EC or the USA is $1,500,000 per head, but in "poor" countries such as China, it is only $150,000.[4] [The disparate figures are derived from peoples' ability-to-pay for damage insurance]. In global cost/benefit analysis, this means therefore these economists discard a real Chinese life ten times more easily than a real life in the EC or the USA. This is an example of how you keep the damage costs below the emissions mitigation costs. You just quietly devalue the lives of people who are not in the EC and the USA and hope that nobody questions "business-as-usual" with genocide written into the bottom line.

Economists of this school have also suggested that *"the economic perspective in global cost-benefit analysis attempts to condense the complex set of impacts over space, time and sectors by summarising them in a scalar measure of value... the fact that the scalar is in monetary units is not really crucial:* ***It could be in spotted-owl equivalents****"*.[5] For GCI this is evidence of confusion in the reasoning of these economists at this fundamental level. On the one hand they say that monetary units are not crucial [spotted-owl equivalents will do just as well as money] and on the other hand they say that monetary units are crucial [peoples varied ability-to-pay—in money—determines their rights and their relative worth].

The question that haunts their confusion is this: Why if one spotted owl equals one spotted owl, doesn't one human equal one human? In the twisted logic of global cost/benefit analysis, it turns out that people do not have an equal right to survive even though spotted owls do. This is another way of saying that people do not have an equal right to be here in the first place; your rights are proportional to your income. At sub-global levels of economic debate, this kind of wrangle is of a familiar vintage. It is the substance of the traditional left/right arguments where those without the money make "equity-for-equity's sake" (principle) arguments, whilst those with the money make "efficiency-for-efficiency's sake" (practicality) arguments. Whatever the rights and wrongs of this approach, equity and efficiency are seen as being traded off against each other. Much of the history of our political economy is a story about this false dichotomy. At a global level this kind of economic discrimination is simply suicidal. It is discriminatory on a greater scale than before. But it is also dangerous and different in a manner which is without precedent. First,

[2] World Development Report 1992, p. 165.

[3] Measures such as carbon taxes, tradeable-emissions-permits and joint-implementation.

[4] "Global Warming Damage Costs: Some Monetary Estimates" by Samuel Fankhauser (with input from Pearce and Nordhaus). Working Paper GEC 92-29 from C-SERGE, the UK's Centre for the Social and Economic Research of the Global Environment.

[5] Prof. William D. Nordhaus in a letter to GCI dated 28/2/94.

there is nowhere else to go. There isn't a global carpet under which the waste, the pollution and the "poor" can be swept and then ignored. The causes and the influences of these things in the system needs to fundamentally inform the analysis undertaken.For practical as well as ethical purposes, each human being is the fundamentally equal unit for measuring sustainability. This is true because large numbers of these are not going to accept being made the discards of a sub-system which values itself 10:1 over everyone else, let alone a system which hasn't demonstrated sustainable consumption patterns since industrialisation began.

* * * * * * *

GCI was accused by Prof. William Nordhaus of failing to test ideas in (what he called) the *"political and economic market-place"*. In consequence we circulated the following text through the InterNet. The text plus the support attracted was published in the UK *Guardian* (1/7/94). It is included here as market research and evidence of the rejection of the C-SERGE global-cost/benefit analysis life-evaluation methodology. This research will continue until at least March 1995.

> "Protecting the world environment requires that development be sustainable. Some time ago main-stream economists explicitly set out to capture the sustainable development agenda for the economics profession. In this pursuit and with much public money, they invented the technique they call "global cost/benefit analysis" (G-CBA). Global warming and the cost and benefits of climate change are now assessed by them in these monetary terms. And this assessment is being aggressively pushed by the economists in the UN's Intergovernmental Panel on Climate Change (IPCC). Part of this exercise, they assert, entails giving cash values to human lives. They accept there are going to be hundreds of thousands of deaths worldwide as a result of global climate changes. A recent research paper from the UK-Government-funded C-SERGE, the UK's "Centre for the Social and Economic Research of the Global Environment", states that the cash value of a "statistical life" in the EC or the USA is $1,500,000 per head, but in China it is only $150,000. In G-CBA, this means that, as an economist, you help capture the sustainable development agenda for your profession by discarding a real Chinese life ten times more easily than a real life in the EC or the USA. Ironically, these lives are now at risk as a result of damage to the global environment for which citizens in the EC and the USA have been and are at least ten times more responsible per head than citizens in China. There is, of course, a foreign policy cost associated with this since the population of the EC and the USA is outnumbered 10–1 by everyone else. The need to value human rights as equal; is prudent as well as perennial".

Tony Cooper, Global Commons Institute—Nigel Dower, Aberdeen University Dept of Philosophy, Politics and Int. Relations—Antoine Sendama, Africa Water Network—Victor Anderson, Author *Alternative Economic Indicators*—Jon Scott, Prof. and Chairman Atmospheric Sc. University at Albany New York—Tim Lenton, Robinson College Cambridge University—Ulrich Leonig, Director Centre for Human Ecology, Edinburgh University—Cynog Dafis, Ceredigion & Pembroke North MP—Paul Spray, Christian Aid UK—John Mead, Christian Ecology Link—Grace Akumu, Climate Network Africa (Kenya)—Ann Heidenreich, World Council of Churches—Shelley Braithwaite, Earth Action Resource Centre—Dan Hinckley, Earthweb Project USA—Dr John Whitelegg, Ecologica Ltd Lancaster UK—Nicholas Hildyard, *Ecologist Magazine*—Wagaki Mwangi, EcoNews Africa—Rob Sinclair, Environment Liaison Centre International—Heinz Greijn, Environment Liaison Centre International—Martin Hogan, Essex University—John Hontelez, Chairman Friends of the Earth International—Charles Secrette, Director Friends of the Earth UK—John Whiting, Global Commons Trust UK—John Gordon, Global Environmental Research Centre—George Monbiot, Visiting Lecturer Green College Oxford—Gosta Lynga, Green Party USA—Mike Feinstein, Green Party California—Patrick Samphire, Green Party Colchester—Johannes Poehlmann, Green Party Germany—Frank de Jong, Leader, Green Party of Ontario—Mike Woodin, Green Party Oxford City Council—Peter Doran, Green Party of Northern Ireland Region—Jan Bojer Vindheim, Green Party Norway—Claes Roxbergh, Green Party Sweden—Penny Kemp, Green Party Executive UK—Mike Woodin, Green Party Oxford City Council—Jim Berreen, Environment Speaker Green Party UK—Dr Richard Lawson, Health Speaker Green Party UK—Alan Francis, Green Party Euro-candidate Beds and Milton Keynes—Phil Ferraro, Institute of Bioregional Studies—Thomas Pattern, Institute of Education London University—Andrew Samuels, Jungian Analyst—Dominic Walubengo, Kenya Energy and Environment Organisations—Gilbert Arrum, Kenya Energy and Environment Organisations—Suchit Nanda, Live Wire BBS, Bombay, India—Mark Norman, Macclesfield Green Party—Piers Stephens, Manchester University, Philosophy Department—Ian Douglas, Manchester University, Prof. School of Geography—Keekok Lee, Manchester University, Snr lecturer, Philosophy Department—Harry Lesser, Manchester University Snr lecturer, Philosophy Department—Oduor Ong'wen, Multilateral Development Bank—Simon Zadek, New Economics Foundation—Dr Julian E. Salt, Peace Studies Department, University of Bradford—

Martin Saning'o, Olkonerei Integrated Pastoralist Survival Project, Tanzania—Mike Smith, Oxford University Philosophy Dept—Ian Ramsey, Rainforest Action Group, Scotland—Angie Zelter, Reforest the Earth—Alistair MacIntosh, Reforesting Scotland, Development Director—Brendan Hill, Reforesting Scotland—Andy Wightman, Reforesting Scotland—Gerald Leach, Stockholm Environment Institute—Toby Champion, Sussex University—John Barkham, University of East Anglia, Snr Lecturer Sch. of Environment Sc.—Alan Long, VEGA—Tom Wakeford, York University Biology Department (and numerous other unaffiliated individuals).

Controlling Carbon Equity, Efficiency and Participation in Possible Future Agreements to Control Fossil Fuel Carbon Emissions

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Abstract—It is not possible for OECD nations to control the future concentration of atmospheric CO_2 on their own. They cannot delay the date by which any greenhouse warming occurs by as much as ten years even at the end of the next century. Without the engagement of non-OECD nations, atmospheric concentrations of CO_2 will likely grow to more than double preindustrial concentrations, and economic damages will be delayed only marginally in developing nations. It is therefore essential that agreements aimed at stabilising fossil fuel CO_2 emissions be inclusive. We also find that cooperation pays. The global cost of stabilising emissions with regions acting independently may be twice as high as cooperative agreements.

Equity issues add another dimension to the problem. Even if it is determined that cooperative agreements are preferred, this does not determine either the preferred implementation instrument or the relative burden to be borne by different regions. The allocation of burden is essentially a political and ethical issue, but it cannot be divorced from national and regional self interest.

Introduction

In June 1992, at the United Nations Conference on Environment and Development in Rio de Janeiro, the nations of the world took an important step in protecting the global commons when they signed the UN Framework Convention on Climate Change (FCCC). This historic document, along with the Vienna Convention on the Protection of the Ozone Layer and its Montreal Protocol are the first global accords designed to protect the earth's atmosphere. Each of these agreements resulted from a recognition by the international community that the scale and structure of human economic activity had begun to threaten the sustainability of our global habitat.

The negotiations of each of these agreements, particularly the FCCC, was complicated by the complexity of the physical processes that govern the atmosphere and the variety of national economic institutions, cultures and interests that govern the negotiating positions of the participants. The negotiators were able to frame a convention objective that was specific to the protection of the climate system, namely to achieve "stabilisation of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". (FCCC, 1992, p. 5).

The design of the initial mitigative steps towards this objective however, accounted for the diversity of interests and historic sources of anthropogenic emissions. The Parties to the Convention specifically acknowledge however, the importance of broad international participation in addressing global climate change in the Preamble. The Parties acknowledge however, that the nature of participation will differ according to their common but differentiated responsibilities and respective capabilities and their social and economic conditions". (FCCC, 1992, p. 2).

The explicit recognition of differentiated responsibility, capability, and differing social and economic conditions was an important negotiating objective of many countries, particularly developing ones, during the negotiations. One outcome of this position is that the convention differentiates between commitments of all countries (Article 4.1), and those of developing countries, and other Annex 1 Parties (Article 4.2). Article 4.2 commits Annex 1 countries to take national actions which limit their anthropogenic greenhouse gas emission and protect and enhance sinks. In fact these national policies are to be taken "with the aim of returning individually or jointly to their 1990 level..." their net greenhouse gas emission by the end of the decade. Undertaking this differentiated commitment would "demonstrate that developed countries are taking the lead..." in meeting the objective of the Convention.

There has been little analysis, however, of the relationship between the economic implications and equity considerations of common versus differentiated approaches to emission mitigation. What if the general approach found in Article 4 of the Convention were extended and made more stringent in future amendments or protocols by requiring further mitigation actions by Annex 1 parties? Would this be effective in meeting the objective of the Convention? Would the distribution of benefits from action between developed and developing countries match the distribution of costs for those actions? These are the types of issues that this paper seeks to raise in a preliminary way.

Approach

Overview

The purpose of this paper is to identify some conditions under which agreements to reduce fossil fuel CO_2 emissions might be successfully implemented. We use a reduced form version of the Global Change Assessment Model (GCAM). The GCAM provides tools which cover both economic and bio-geophysical relationships. The reduced form version of GCAM, MiniCAM, is an integrated set of models that address complementary facets of the climate change problem. We rely on the Edmonds-Reilly-Barns Model (ERB) for energy related greenhouse gas emissions. Other emissions trajectories, particularly land-use related emissions, are taken from the IPCC, IS92 scenarios. Atmospheric composition, radiative forcing, global mean temperature change, and sea level rise are generated by the MAGICC model which follows Wigley and Raper (1992). Damage functions are taken from the MERGE model of Manne et al. (1993).

Modelling Energy-Related Emissions: The ERB Model

We have used the ERB, version 4.15, to represent energy-economy-greenhouse emissions relationships. The ERB is a well-documented (Edmonds and Reilly, 1985; Edmonds et al., 1986), frequently used, long-term model of global energy and fossil fuel greenhouse gas emissions. The model can be thought of as consisting of four parts: supply, demand, energy balance, and greenhouse gas emissions. The first two modules determine the supply of and demand for each of six major primary energy categories in each of nine global regions. The energy balance module ensures model equilibrium in each global fuel market. (Primary electricity is assumed to be untraded; thus supply and demand balance in each region.) The greenhouse gas emissions module is a set of three post-processors which calculate the energy-related emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The original version of the model is documented in Edmonds and Reilly (1985), while major revisions are discussed in Edmonds et al. (1986). This model is currently configured to develop scenarios for benchmark years: 1990, 2005, 2020, 2035, 2050, 2065, 2080 and 2095.

Energy demand for each of the six major fuel types is developed for each of the nine regions. Five major exogenous inputs determine energy demand: population; labour productivity; exogenous energy end-use intensity; energy prices; and energy taxes, subsidies, and tariffs.

The model calculates base GNP directly as a product of labour force and labour productivity. An estimate of base GNP for each region is used both as a proxy for the overall level of economic activity and as an index of income. The base GNP is, in turn, modified within the model to be consistent with energy-economy interactions. The GNP feedback elasticity is regional, allowing the model to distinguish energy supply dominant regions, such as the Mideast, where energy prices and GNP are positively related, from the rest of the world where the relationship is inverse.

The exogenous end-use energy-intensity improvement parameter is a time-dependent index of energy productivity. It measures the annual rate of growth of energy productivity that would continue independent of such other factors as energy prices and real income changes. In the past, technological progress and other non-price factors have had an important influence on energy use in the manufacturing sector of advanced economies. Including an exogenous end-use energy-intensity improvement parameter allows scenarios to be developed that incorporate either continued improvements or technological stagnation assumptions as an integral part of these scenarios.

The final major energy factor influencing demand is energy prices. Each region has a unique set of energy prices derived from world prices (determined in the energy balance component of the model) and region-specific taxes and tariffs. The model can be modified to accommodate nontrading regions for any fuel or set of fuels. The model assumes that regions do not trade solar, nuclear, or hydroelectric power, but all regions trade liquids (both oil and synoil), gases (natural and syngas), and solids (coal and biomass).

The energy-demand module performs two functions: it establishes the demand of energy, and its services, and it maintains a set of energy flow accounts for each region. Oil and gas are transformed into secondary liquids and gases that are used either directly in end-use sectors or indirectly as electricity. Hydro, nuclear, and solar electric or fusion are accounted for directly as electricity. Nonelectric solar energy is included with conservation technologies as a reduction in the demand for marketed fuels.

The four secondary fuels are consumed in order to produce energy services. Energy is consumed by three end-use sectors: residential/commercial, industrial, and transportation.

The demand for energy services in each region's end-use sector(s) is determined by the cost of providing these services and by the levels of income and population. The mix of secondary fuels used to provide these services is determined by the relative costs of providing these services using each alternative fuel. The demand of fuels to provide electric power is then determined by the relative costs of production, as is the share of oil and gas transformed from coal and biomass.

Energy supply is disaggregated into two categories, renewable and non-renewable. Energy supply from all fossil fuels is related directly to the resource base by grade, the cost of production (both technical and environmental) and to the historical production capacity. The introduction of a graded resource base for fossil fuel (and nuclear) supply allows the model to explicitly test the importance of fossil fuel resource constraints as well as to represent fuels such as shale oil, in which only small amounts are likely available at low costs but for which large amounts are potentially available at high cost.

Note here that nuclear is treated in the same category as fossil fuels. Nuclear power is constrained by a resource base as long as light-water reactors are the dominant producers of power. Breeder reactors, by producing more fuel than they consume, are modelled as an essentially unlimited source of fuel that is available at higher cost.

A rate of technological change is also introduced on the supply side. This rate varies by fuel and is expected to be both higher and less certain for emerging technologies.

The supply and demand modules each generate energy supply and demand estimates based on exogenous input assumptions and energy prices. If energy supply and demand match when summed across all trading regions in each group for each fuel, then the global energy system balances. Such a result is unlikely at an arbitrary set of energy prices. The energy balance component of the model is a set of rules for choosing energy prices which, on successive attempts, bring supply and demand nearer a system-wide balance. Successive energy price vectors are chosen until energy markets balance within a prespecified bound.

Given the solution of the energy balance component of the model, greenhouse gas emissions for CO_2, CH_4 and N_2O are calculated by applying emissions coefficients. Emissions coefficients for CO_2 are as follows:

• liquids	19.2 TgC/EJ
• gases	13.7 TgC/EJ
• solids	23.8 TgC/EJ
• carbonate rock mining	27.9 TgC/EJ

Modern biomass is treated as if its carbon absorption occurred in the year of release. This approximation can either underestimate or overestimate actual net annual fluxes depending upon whether the underlying stock of biomass is either expanding or contracting. (See Edmonds and Barns, 1990.)

Modelling Atmosphere, Climate and Sea-Level: The MAGICC Model

The analysis of atmospheric composition, climate change, and sea level rise uses the MAGICC model following Wigley and Raper (1992).

The concentration of CO_2 in the atmosphere is determined using a reduced form carbon cycle model. The model is balanced, that is, the model reproduces current atmospheric concentrations in a manner which does not resort to directly pairing emission sources and sinks. Two sink terms are considered, ocean and terrestrial. The ocean sink employs a convolution integral representation, based on Maier-Reimer and Hasselmann (1987). The terrestrial sink is modelled as four linked boxes. An important feature of the model is that it provides a pathway by which atmospheric CO_2 concentrations affect terrestrial carbon storage. This pathway allows the carbon cycle to be balanced, though it should be noted that this mechanism is a gross oversimplification of what is currently known regarding the carbon cycle, and great uncertainty remains as to the disposition of anthropogenic emissions. (See for example, Wisniewski and Lugo, 1992 and IPCC, 1992.)

Methane is modelled as having two sinks, atmospheric chemical reactions and soils. For nitrous oxide and the halocarbons only the atmospheric sink is considered. It is well known that atmospheric sink rates are not constant. For methane, the availability of hydroxyl radicals is a governing factor which in turn depend on the concentration of CH_4 and the emission rates for carbon monoxide (CO), oxide of nitrogen (NO_x), and volatile organic compounds (VOCs). The model explicitly considers the effect of CO, NO_x and VOC emissions on the atmospheric removal rate.

Sulphur emissions are short lived, but their effect on climate is thought to be significant. Unlike the "greenhouse" gases, they exert a cooling effect. Because of their short lifetimes, no atmospheric stock model is needed.

Radiative forcing varies by gas. The effect of increases in the concentration of carbon dioxide in the atmosphere increases radiative forcing with the log of the concentration. The changes in radiative forcing associated for methane and nitrous oxide are computed as per Shine et al. (1990). These methods consider direct and indirect effects on radiative forcing, as well as the effects of absorption band overlaps.

The radiative forcing associated with halocarbons has two components, a direct component and an indirect ozone component. Both are modelled.

The presence of sulphate aerosols in the atmosphere is presently felt to have a strong local cooling effect. This effect is manifest through three pathways: scattering and absorption of shortwave (solar) radiation effects, cloud reflectivity effects, and cloud persistence effects (IPCC, 1992). This effect on radiative forcing is modelled explicitly.

The change in global mean temperature depends on the sum of the changes in radiative forcing, climate sensitivity, and ocean thermal inertia. The climate sensitivity is reflected by the change in global mean temperature associated with a doubling of the preindustrial concentration of atmospheric CO_2, after direct and feedback effects (for example, water vapour, ice albedo, and clouds) are taken into account. The most commonly cited range of climate sensitivity is 1.5 to 4.5°C, with a "best guess" value of 2.5°C. Ocean thermal lag is computed using an upwelling-diffusion model. The model in turn depends critically on parameters for mixed-layer depth, oceanic vertical diffusivity, the upwelling rate, and the temperature change of high-latitude sinking water relative to the global-mean change.

Sea level rise is computed as the sum of two terms, thermal expansion and meltwater runoff (Wigley and Raper, 1987, 1992). Thermal expansion is computed from the oceanic upwelling-diffusion model referenced above. Meltwater is the sum of contributions from three sources: small glaciers, Greenland, and Antarctica. These in turn are driven by equilibrium temperature change.

Global mean temperature is mapped into damages for 11 regions using results from 10 general circulation models (GCM). The 11 regions identified for damage calculations are: 1. USA, 2. Canada, 3. Western Europe, 4. Japan, 5. Australia & New Zealand, 6. Eastern Europe and the former Soviet Union, 7. China, 8. Mideast, 9. Africa, 10. Latin America, 11. South and East Asia. The 10 GCMs are 1. GMT,; 2. GISS,; 3. GFDL,; 4. LLNL,; 5. UKHi,; 6. OSU,; 7. UKLo,; 8. CCC,; 9. MPIL,; and 10. UKTr, .

Output for each GCM is normalised to its own internal climate sensitivity. Wigley (1994) has observed that for any individual model that climate sensitivities are essentially linear with transient temperature when the transient temperature is below the climate sensitivity.

Modelling Damages: The MERGE Model

We have adopted the damage functions from the MERGE model (Manne et al., 1993) for each of the 11 regions. MERGE considers damages of two types, market and non-market damages. Market damages are damages which would appear directly in national accounts. These include such damages as those from capital stock loss due to sea level rise, reduced agricultural productivity, and increased energy requirements for cooling. Market damages are modelled as a function of regional GDP and regional temperature change. Market damages are calibrated to yield a loss of 0.0025 of GDP for ΔT=2.5°C in developed nations and 0.0050 of GDP for developing nations. They rise exponentially with temperature. They are assumed to be zero in 1990.

Non-market damages are measured as a willingness to pay to avoid climate change in the region. These damages include the value to residents of the biological setting in which they currently reside compared to that anticipated under climate change. For example, there is assumed to be a cost associated with the replacement of oak forests by pine forests in a locale. Willingness to pay varies by region and is a function of regional GDP per capita and regional temperature change. Damages are calibrated to be 0.02 of GDP for per capita GDP of $40,000 (Manne et al., 1993). Damages rise with income and rise sharply with temperature.

Because much of the damage literature is based on regional and sectoral work that references the GISS model, regional temperature changes are normalised by those of the GISS model.

Reference Cases

Assumptions

To provide a basis for comparison, a reference case was constructed which we call Case 1. For ease of reference, an attempt has been made to tune the model to reflect the IPCC (1992) emissions scenario, IS92a. IPCC (1992) presents a set of six scenarios in a series referred to as the IS92 scenarios. These scenarios are labelled

Table 1. Key assumptions	
Parameter	Assumption
Exogenous end-use energy intensity improvement rate	1%/year in OECD and EEFSU[1] 2%/year in China, rising to 3.5%/year in 2095. 0.5% in ROW, reaching[2] 1.0%/year in 2095.
Fossil fuel resources	
Oil	18,011 EJ
Gas	17,451 EJ
Coal	271,000 EJ
Uranium	14, 423 EJ (extend w. breeder option)
Conventional fossil fuel power plant efficiency	33% in 1990 66% by 2050
Global population (year 2100)	$11{,}312 \times 10^6$
Biomass energy resource	400 EJ/year
Biomass price	
20% of the resource base available at	$2.50/GJ
80% of the resource base available at	$4.40/GJ
Global GNP growth	2.3%/year

[1]EEFSU = Eastern Europe and the former Soviet Union
[2]ROW = Rest of the World.

IS92a through IS92f. The extreme scenarios are IS92e (the highest carbon emissions case) and IS92c (the lowest carbon emissions case). IS92a falls between the extremes. Alcamo et al. (1994) have shown that IS92c and IS92e encompass a majority of the non-IPCC fossil fuel carbon reference scenarios in the literature, and that IS92a is a case which lies near the heart of the distribution of non-IPCC fossil fuel carbon reference scenarios.

Case 1 employs the same population and GNP assumptions as its IS92 counterpart. Other key parameters have been adopted to match global energy and fossil fuel carbon emissions. We report some of the key assumptions which govern the behaviour of the model in Table 1. A full description of reference case model inputs and outputs is given in an appendix which is available upon request.

The biomass resource constraint was developed to be consistent with agricultural requirements of associated population and income levels, Edmonds and Reilly (1985). While an enormous supply of energy is available in the form of shale oil, this resource is generally quite expensive to produce with current technologies and therefore is not a major factor in the reference scenario. The uranium resource base is assumed to be extended if a breeder reactor technology is adopted.

Energy and Fossil Fuel Results

Energy and fossil fuel carbon emissions closely mirror those developed for IS92a. These are shown in Figs 1 and 2. Figure 3 compares regional energy consumption between IS92a and Case 1. Fig. 4 shows the global energy production by fuel for this same case.

In Case 1 the energy system grows from its 1990 level of approximately 340 EJ/year to approximately 1410 EJ/year. In Case 1

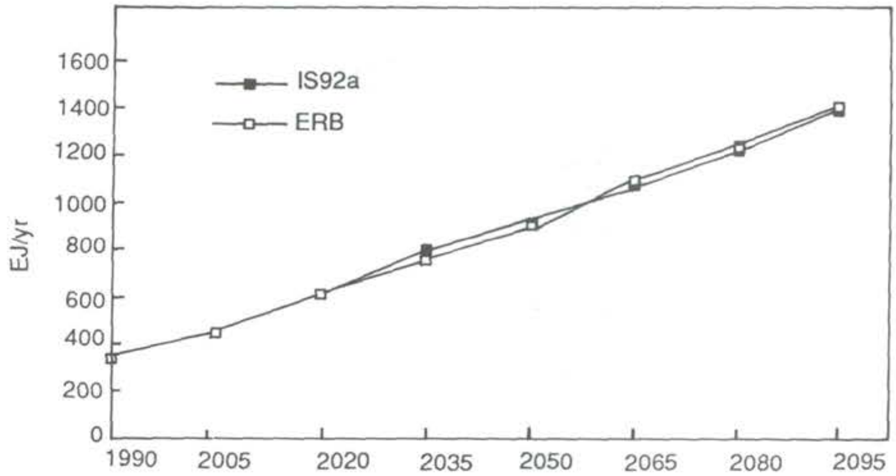

Fig. 1. Global primary energy consumption: IS92a vs ERB base

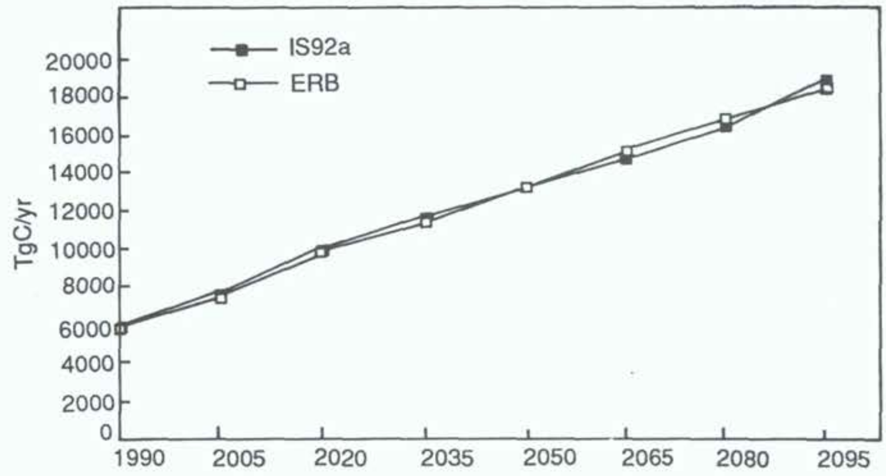

Fig. 2. Global fossil fuel carbon emissions: IS92a vs ERB base.

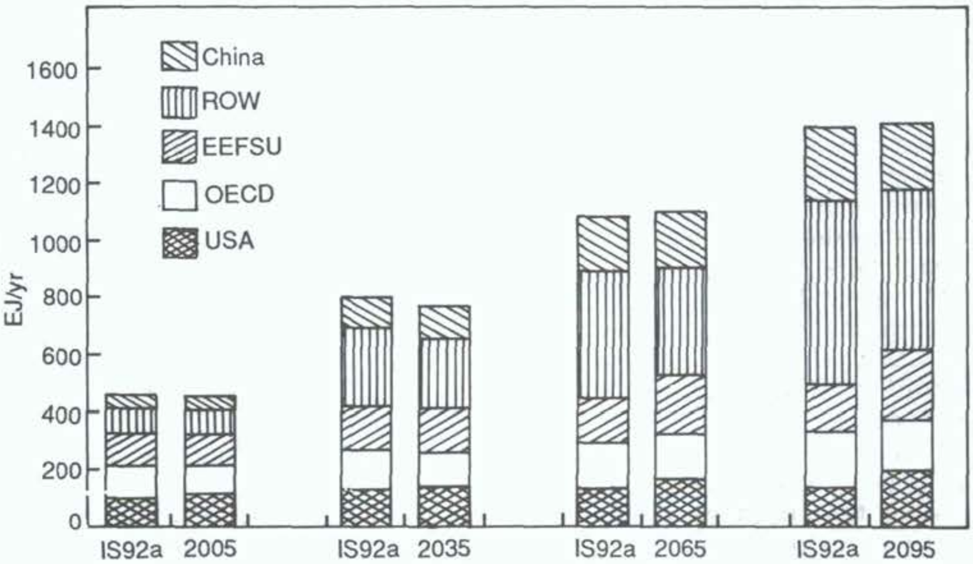

Fig. 3. Regional primary energy consumption: IS92a vs Case 1.

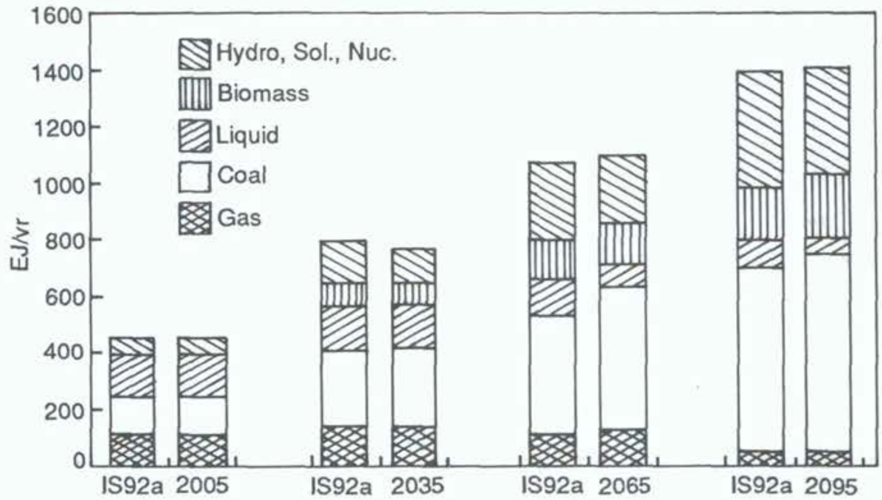

Fig. 4. Global energy consumption, by fuel: IS92a vs Case 1.

conventional oil and gas production peaks in the year 2050, and declines thereafter. Coal production grows steadily in Case 1 from approximately 100 EJ/year in 1990 to almost 700 EJ/year in 2095. Both biomass and solar electric[1] technologies show significant growth. By the year 2095 they provide 295 EJ/year in Case 1.

The regional distribution of fossil fuel CO_2 emissions changes greatly over the period of analysis. OECD regional emissions almost double from 1990 levels. Emissions in the former Soviet Union and Eastern Europe more than double from 1990 levels. Moderate economic growth in the developing world fuels emissions growth at higher rates than in the OECD, Eastern Europe, and the Former Soviet Union. By the year 2095 developing nations emissions grow by more than a factor of six. Their share of global emissions rises from about 25 to 45% over this period.

Atmosphere, Climate and Sea Level

The ERB provides information with regard to fossil fuel CO_2, CH_4, and N_2O emissions. These emissions represent only a partial set of anthropogenic fluxes of these gases, not the complete array of greenhouse gases. Case 1 emissions rates for all gases are consistent with those of IS92a. The time path for atmospheric carbon dioxide in Case 1 is shown in Fig. 5. By the year 2100 the concentration of atmospheric CO_2 has risen above 700 ppmv. By the year 2060 the concentration of CO_2 is 557 ppmv, more than double the preindustrial level.

Interestingly, in 2060 the ocean thermal lag holds mean global temperature change, relative to 1990, to only 1.75°C, though equilibrium warming at that concentration of CO_2 is 2.5°C, excluding the effects of other greenhouse gases. By the end of the century, Fig. 6 shows mean

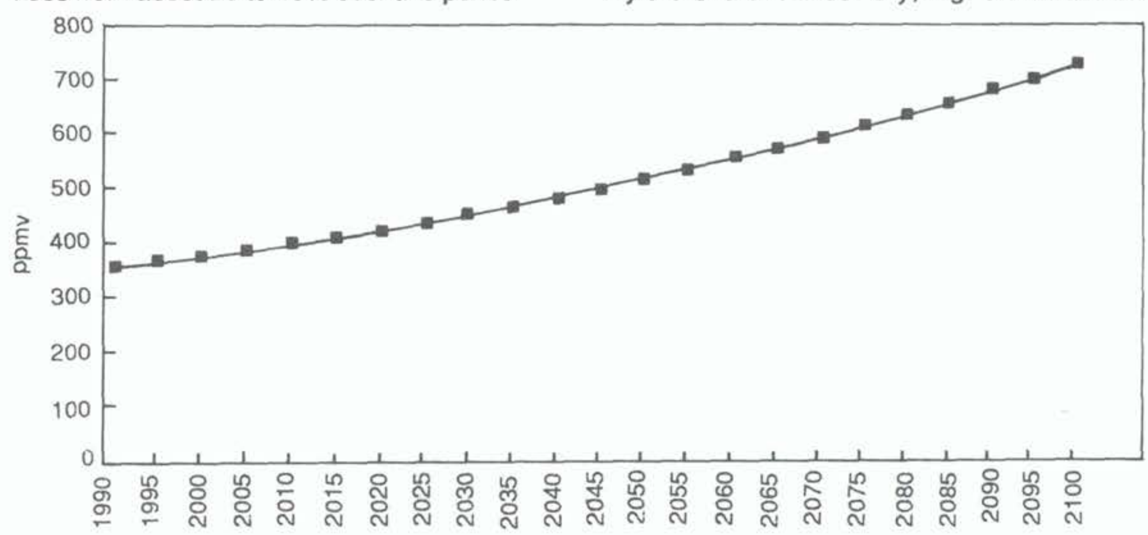

Fig. 5. Atmospheric CO_2 concentration: Case 1.

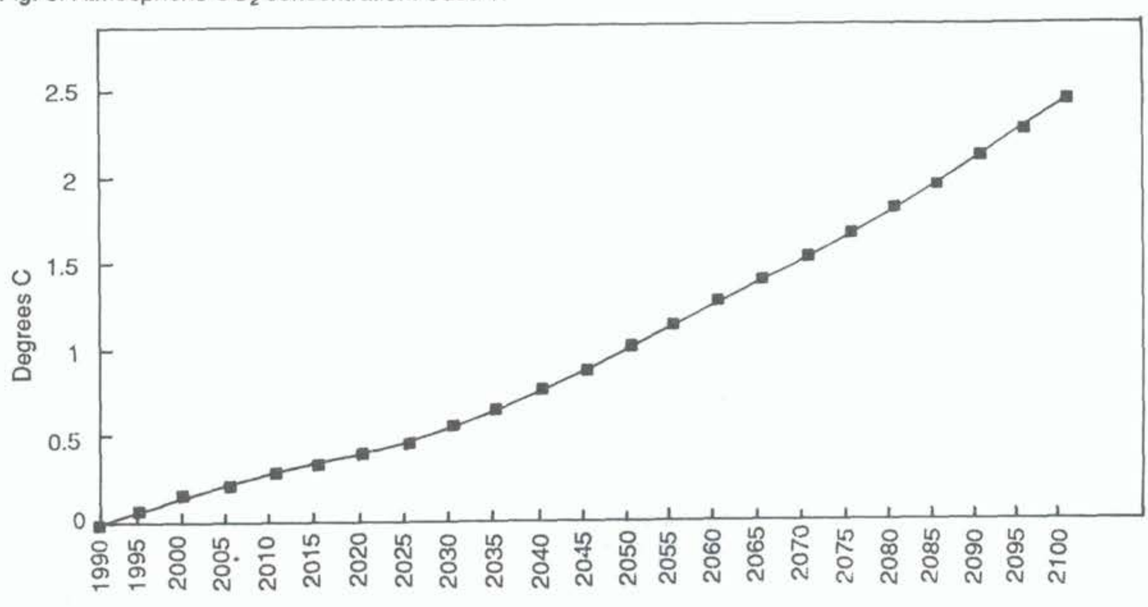

Fig. 6. Global mean temperature increase: Case 1.

[1]Solar electricity is a general category which includes all non-carbon emitting electricity technologies other than nuclear, hydro, and biomass. Thus fusion, wind, geothermal, and OTEC are included in addition to photovoltaic and power tower technologies.

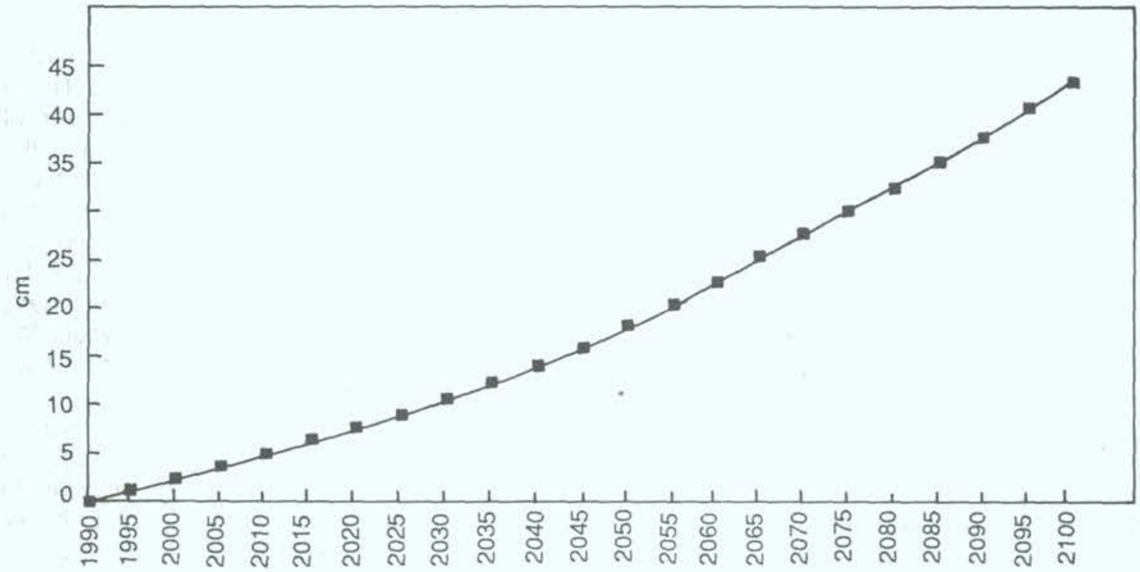

Fig. 7. Global mean sea-level rise: Case 1.

global surface temperature is more than 2.4°C higher than in 1990.

Sea level rises slowly and is 43 cm higher in 2100 than in 1990 as shown in Fig. 7.

Damages

Damages are computed for Case 1 using the MERGE damage function. It is assumed that damages are zero in 1990, but vary with temperature thereafter. Annual losses as a fraction of GNP rise from zero in 1990 to 3.4% by 2100. Non-OECD damages are somewhat less than OECD damages as a fraction of GNP, primarily because OECD willingness to pay is significantly greater than outside the OECD. Non-OECD damages eventually reach 2.9 percent of GNP in the year 2100.

The present discounted value of damages depends on the discount rate chosen. At a zero interest rate damages are 1.4% of global GNP over the period 1990 to 2100. But at a discount rate of 8% they have declined to only 0.08% of present discounted GNP. At a 5% discount rate they are 0.28% of GNP. A discount rate of 5% represents the long term rate at which an average dollar allocated to investment activities yields additional production. It can be interpreted as a rate of trade between the present and future. Thus, if a dollar of damage can be avoided today, and that dollar is invested, it could produce sufficient product to compensate for $1.05 in one year. Lower discount rates are sometimes used to reflect the fact that the investment does not occur. For example, if the savings rate is 20% then only $0.20 of the dollar saved today will be set aside toward investment, and one year hence only $0.21 of additional product will be available. The discount rate has been a matter of some discussion with regard to climate, with standard (5 to 10%) rates advocated by for example, Nordhaus (1992) and lower discount rates advocated by for example Cline (1992).

Energy, Emissions, and Atmosphere Drastic OECD Actions

We next examine the consequences of immediate and dramatic OECD emissions fossil fuel emissions reductions. We assume that OECD carbon emissions are reduced to 50% of 1990 levels by the year 2005 and are reduced to 7% of 1990 emissions by the year 2095. We refer to this dramatic unilateral action as Case 2. Case 2 has been constructed to reveal the degree to which OECD nations, acting alone, can affect atmospheric concentrations of greenhouse gases, and the rate and timing of climate change. Figure 8 shows the fossil fuel carbon emissions trajectories for Cases 1 and 2. The arbitrary unilateral emissions reduction is assumed to be achieved by a tax levied in the OECD on carbon production and use, though other policy instruments could be used to achieve the desired result, (for example, tradeable permits, or regulatory emissions control measures). We note that global emissions reductions are lower than OECD emissions reductions due to the fact that lower energy use in the OECD nations results in lower demand for imported oil and gas from non-OECD nations and consequently leads to lower world prices for these fuels and hence higher non-OECD use of fossil fuels.

There is an implicit "off shore" effect through the lower energy prices. That is, because energy prices are lower in the non-OECD world, these countries will tend to have a comparative advantage in energy intensive goods. The implicit effect is small in this specification of the ERB.

The effect of reduced emissions on atmospheric CO_2 concentrations is given in Fig. 9. While the reduction in OECD emissions reduces the atmospheric concentration of CO_2 in the year 2095 by 44 ppmv, the year in which atmospheric concentrations reach 550 ppmv or "double" the preindustrial concentration of CO_2 is delayed by only 7 years, from 2059 to 2066. Thus, while radical reductions in OECD emissions would produce a delay in the date at which any CO_2 concentration is attained, the delay is modest, and the upward trend in atmospheric CO_2 concentrations remains strong.

The effect of the cessation of emissions by OECD nations on the time path of temperature and sea level are shown in Figs 10 and 11. It is interesting to note that these paths diverge relatively less than the paths for atmospheric concentrations. This is at least in part due to the cessation of all greenhouse related emissions including those of sulphur. Since sulphur has a cooling effect on the atmosphere, reductions in its emission tend to have the opposite effect on temperature as reductions in carbon emissions. As was true in the case of atmospheric CO_2 concentrations, temperature continues to rise, and the date at which a given temperature increase is attained is delayed only marginally. For example, a 2°C temperature increase occurs in the year 2087 for Case 1. In Case 2 this same temperature change is reached 8 years later in 2095.

Annual damages for non-OECD nations are shown in Fig. 12. Results are based on the UKMO transient scenario with a climate sensitivity of 2.5°C. While present discounted, cumulative, global damages are between 26 and 36% lower for the period 1990 to 2100 with dramatic OECD actions, the date at which any level of annual damage is achieved is postponed by less than five years.[2] This is a somewhat shorter delay than for global temperature because damages are linked not only to global temperature but also to income, which continues to rise. The date by which a given burden, measured as damages relative to GNP, is incurred, for non-OECD nations, is delayed by about 7 years by the end of the next century.

We conclude from this analysis that independent of history, even dramatic actions by OECD member states can only marginally affect future concentrations of greenhouse gases.

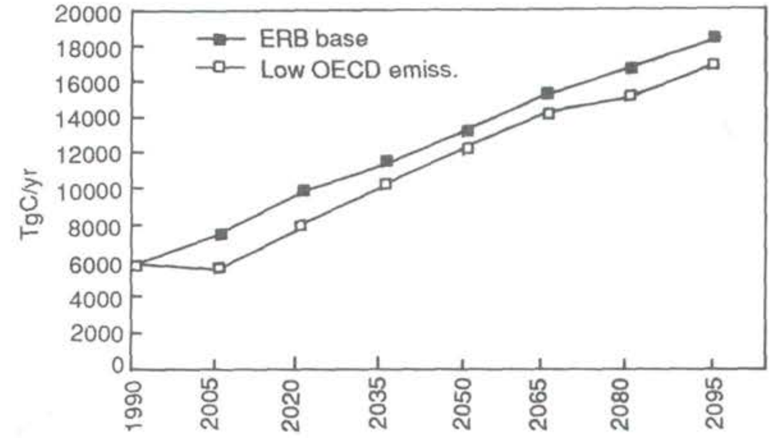

Fig. 8. Annual global fossil fuel carbon emissions: ERB base vs low OECD emissions.

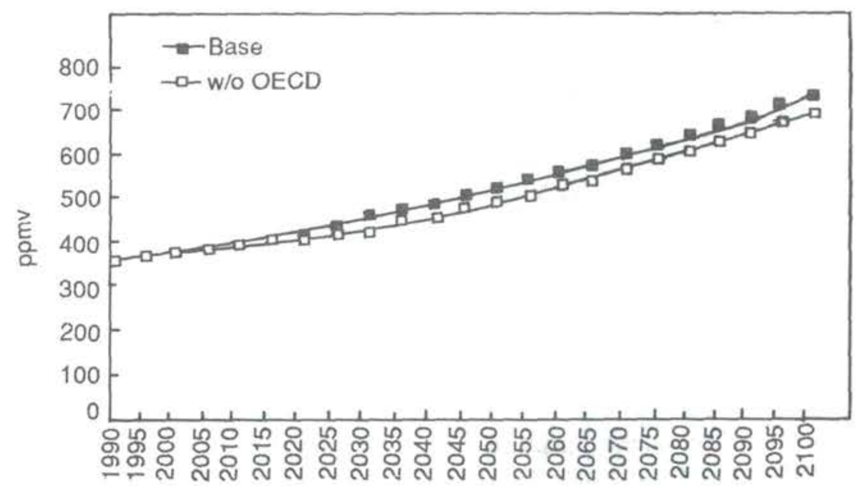

Fig. 9. Atmospheric CO_2 concentration: ERB base vs base with low OECD emissions.

[2]These results refer to calculations using a 5% discount rate. The qualitative results are similar over a range of discount rates ranging from 0 to 8%, though the absolute damages vary by more than two orders of magnitude.

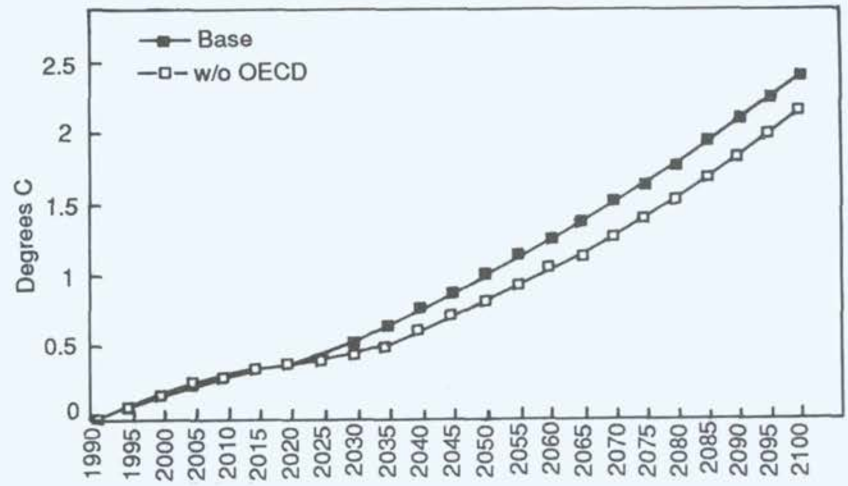

Fig. 10. Global mean temperature increase: ERB base vs base with low OECD emissions.

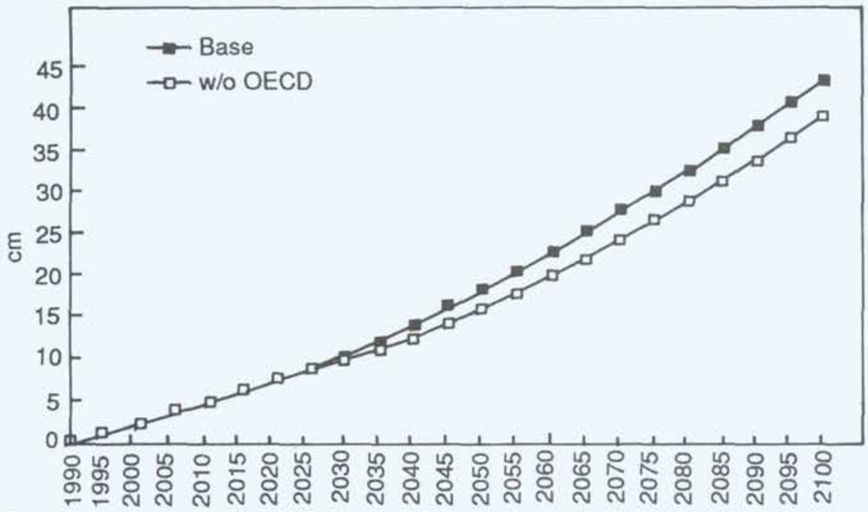

Fig. 11. Global mean sea-level rise: ERB base vs base with low OECD emissions.

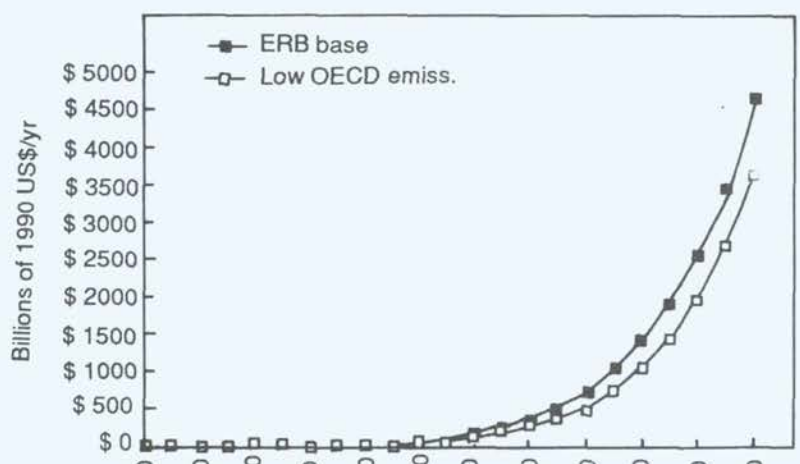

Fig. 12. Annual damages from climate change in the non-OECD countries: ERB base vs low OECD emissions.

Anthropogenic climate change cannot be controlled by the OECD nations alone. Control of future greenhouse gas concentrations is a global problem held in common by all of the nations of the Earth. Further, management of atmospheric concentrations of greenhouse related gases requires participation by many nations, and requires participation by most of the nations controlling major repositories of fossil fuel carbon.

The above analysis depends on the strong assumption that there is no cooperation between the OECD and the rest of the world in reducing emissions. The OECD truly "goes it alone". Emissions reducing technologies developed in response to the higher fossil energy costs in the OECD do not penetrate non-OECD markets. We assume that these technologies are not viable in markets where fossil energy costs are low. In the next section we test the importance of cooperation in reducing emissions.

Cooperative and Non-Cooperative Strategies

If the nations of the world determine to control the composition of the atmosphere, some approaches incur lower costs than others. Cooperation lowers costs. To test this hypothesis, we examine two alternative cases. The first hypothesises the immediate establishment of an agreement to stabilise global emissions as 1990 levels in which participation is universal and cooperative. We model the agreement as if a global tax setting authority had been established which established a carbon tax rate which was then applied by local governments. Revenues from the tax are assumed to remain in the country in which they are collected and recycled in a manner that does not affect the local rate of savings and investment. Free rein is given to joint implementation agreements. We call this Case 3.

The tax rate at which emissions are stabilised is equivalent to the market price of a freely traded carbon emissions permit. It is also true that in a free market setting that the distribution of emissions reductions will be the same in both the global tax case and the tradeable permit case, transactions costs aside. The costs and benefits of participation can be quite different between the two instruments. Whereas costs are internalised under the global tax rate case, the distribution of permits can either increase or decrease the costs of participation to an individual nation.[3]

We consider both the global tax rate and the tradeable permit to be efficient instruments for implementing fossil fuel carbon emissions reductions. In both approaches emissions reductions are undertaken everywhere up to the point where the cost of the next tonne of carbon emissions reduction is exactly equal to the value of the tax or permit.

We contrast the above case with Case 4, an alternative hypothetical agreement in which all nations agree to immediately stabilise their own emissions at 1990 levels indefinitely. But no joint implementation is allowed. Each region is assumed to implement their own emissions reductions with a tax and tax revenues are recycled within that nation in a manner that does not affect the rate of savings and investment. We model this by requiring five regional groups to stabilise emissions: United States, other OECD nations, Eastern Europe and the former Soviet Union, China, and the Rest of the World.

Figure 13 shows the relative costs when comparing the cooperative and individual emissions stabilisation cases.[4] We note several interesting results. The cost to all nations taken together is substantially higher in the individual national stabilisation agreement than in the cooperative agreement. Global costs in Case 4 are approximately double those of Case 3 by the next century.

In addition, the cost of emissions reductions in the OECD in case 4 is actually lower than in the global tax Case 3. Thus the extra burden is borne

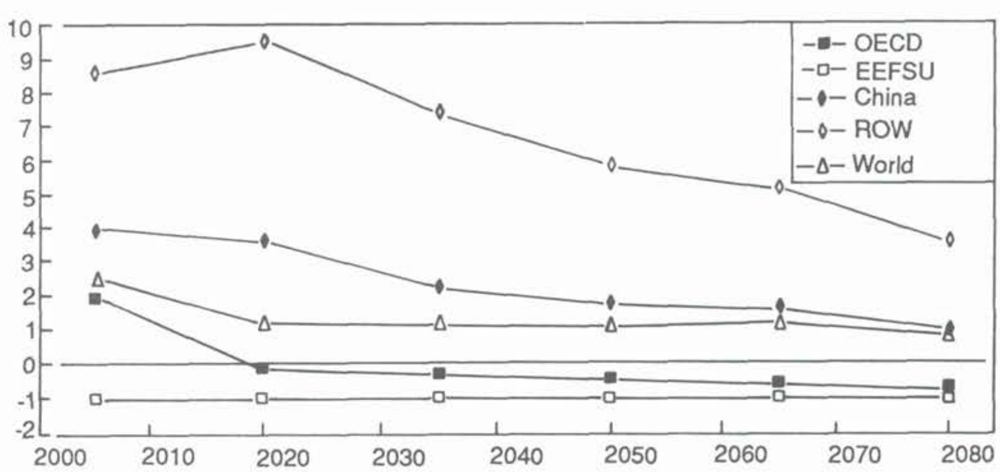

Fig. 13. Relative change in total cost of fossil fuel carbon emissions stabilisation by individual region vs total cost from joint global stabilisation.

[3]We note that this equivalence can be affected by institutional arrangements and social norms. Should either impose either obligations or barriers to individual actions, results from taxes and permit trading can diverge. See for example Cantor et al. (1992) for discussion of these points.

[4]These results are preliminary and subject to change.

entirely by the non-OECD nations. This occurs because in the global tax case the OECD reduces its emissions below 1990 levels, while developing nations emissions continue to grow. The high cost to individual national stabilisation, particularly in developing nations, makes non-cooperative arrangements less attractive than cooperative agreements. It would therefore seem that pursuant to the Framework Convention's admonition to be cost effective in measures undertaken to protect the Earth from dangerous anthropogenic climate change, cooperative solutions, including joint implementation should be seriously considered.

Conclusions

It is not possible for OECD nations to control the future concentration of atmospheric CO_2 on their own. They can delay the date by which any greenhouse warming occurs by less than 10 years even at the end of the next century. Without the engagement of non-OECD nations, atmospheric concentrations of CO_2 will likely grow to more than double preindustrial concentrations, and economic damages will be delayed only marginally in developing nations. It is therefore essential that agreements aimed at stabilising fossil fuel CO_2 emissions be inclusive. We also find that cooperation pays. The global cost of stabilising emissions with regions acting independently may be twice as high as cooperative agreements.

Equity issues add another dimension to the problem. Even if it is determined that cooperative agreements are preferred, this does not determine either the preferred implementation instrument or the relative burden to be borne by different regions. The allocation of burden is essentially a political and ethical issue, but it cannot be divorced from national and regional self interest.

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Methodological Lessons and Results from UNEP GHG Abatement Costing Studies—The Case of Zimbabwe

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Abstract—This article is based on greenhouse gas emissions and greenhouse gas abatement costing studies carried out for Zimbabwe. The study produced an inventory of GHG emissions for the country and assessed the cost of 17 technological options for reducing GHG emissions on the basis of which was developed a set of abatement cost curves one based on a discount rate of 6% and another on 10%.

The study carried out as part of the UNEP greenhouse gas abatement costing studies shows that GHG emission levels as at 1991 were 16.9 million tonnes having increased from a 1982 level of 8.9 million tonnes. The bulk of these emissions (13.9 million tonnes) were related to the use of coal energy; abatement costs range from -Z$821.50 (negative costs) per tonne for the cheapest abatement option to Z$31,645.00 for the most expensive option considered. Assessment of these costs was based on cost items such as capital outlay for an option, related fuel costs and a discount rate set at 6 and 10%.

Emission reductions of 21% in the short term and 39% in the long term were achieved mainly through energy sector interventions. A significant range of these were negative cost options mainly associated with end-use efficiency improvements rather than supply side interventions.

Background

The Zimbabwe case study was carried out as part of the UNEP GHG abatement costing studies. It was a joint effort of researchers at Southern Centre for Energy and Environment in Harare and at the Systems Analysis Department at Riso National Laboratory in Denmark. The results presented here are a summary of a lengthy exercise intended both to shed light on emissions abatement alternatives to address political and development issues of interest to the country and to contribute to the costing methodology for use at the international level.

Although this paper highlights activities related to CO_2 emissions from the energy sector, the broader research effort covered process emissions and emissions of other gases such as methane and nitrous oxides. In any case, the activities treated CO_2 as the primary gas and focused initially on analysing for this gas only and then applying the methods to other gases later.

Analytical Framework

The analytical framework was bounded by the need first to obtain scientific information on emission of GHGs in Zimbabwe (inventories), generating alternatives for reducing emissions, determining the cost of introducing these abatement options up to a set target, and ranking the reduction options as a policy guide.

This involved analysis of the Zimbabwean economy, assessment of base-year inventories of emissions, development of specific models for analysing abatement costs, and development of abatement cost curves for two abatement scenarios.

The economic analysis enabled the development of an appreciation of the economic base from which emissions and reduction costs would be derived and projected into the future. This approach proved to be most crucial for Zimbabwe which is a developing country with very limited information on the structure of its economy and much less on the future of the economy. These constraints were compounded by:

(a) limited confidence on the ability of existing policy instruments to steer the economy towards an emissions abatement path, and
(b) the introduction of a new economic structural adjustment programme whose own outcome was unknown and at best speculative.

The base year inventories which were carried out as phase one of the Zimbabwe country study[1] and were useful in presenting information

[1]UNEP Greenhouse Gas Abatement Costing Studies. Zimbabwe Country Study. Phase One Report. Southern Centre for Energy and Environment, Harare, Zimbabwe and Systems Analysis Department, Riso National Laboratory, Denmark. Department of Energy, Ministry of Transport and Energy, Zimbabwe. August 1992.

on which future emissions would be assessed but more importantly provided a useful methodological prelude to the more difficult exercise of assessing abatement costs and building cost curves.

The analytical methodologies for the UNEP studies were charted out in a set of guidelines specifically designed for the studies and developed as part of the study process.[2] The selection of detailed analytical models was done by the research team. This allowed for the development or selection of tools manageable at the local level and suitable for the data situation in the country. The analysis generally followed the bottom-up approach in analysing energy sector activities and assessing emissions and their projection. It would have been helpful to utilise the top-down analysis in dealing with macro-economic issues but this was hampered first by the lack of a national macro-economic modelling facility and second by the lack of input/output data for the economy.

The emissions assessments were based on a reference scenario showing economic activity levels as per current trends but including changes effected by policy interventions already in place or realistically contemplated. A second scenario, the abatement scenario, evaluated the direct costs of introducing abatement options in the energy sector, manufacturing and agriculture. The direct costs included investment costs, fuel costs and other costs such as operation and maintenance costs. It was assumed here that costs would be financed through an international funding mechanism under the FCCC. Macro-economic impacts of abatement were not assessed because a macro-economic model was not available in the country and could not be developed in the two years of the initial project period. The exclusion of a macro-economic assessment means that the costs calculated under the abatement scenario can be treated as the incremental costs of abatement when the economic activity in the baseline remains unchanged.

Scope of Analysis

The analysis concentrated more on the energy sector which generates the bulk of CO_2 emissions contributing over 90% of all CO_2 emitted in the country. End-use energy activities and supply side interventions were analysed with a view to determining such options as housekeeping interventions, technological interventions and broad macro-economic interventions which would include structural adjustment in the activity levels of the various sectors of the economy.

Emissions from the use of biomass for energy in households and those related to loss of forest as carbon sinks were also assessed. Assessments of the latter, however, only yielded preliminary results due to the low reliability of data on forest cover.

Overview of the Methodology

The methods adopted in the study follow a preparatory search on methods carried out by UNEP and published as Phase One Report of the UNEP GHG abatement costing studies.[3]

This report reviewed several bottom-up and top-down methods for costing GHG abatement. Debate on the use of these methods continued throughout the development of the UNEP methodological guidelines. In the process it became generally agreed that it may not be practical to seek to integrate top-down and bottom-up methods in the analysis but the results from both approaches can be compared. The successful application of either approach for Zimbabwe is limited by the lack of consistent data to support the analysis. The top-down approach which is basically macro-economic modelling would require comprehensive national input/output tables at highly disaggregated levels and the bottom-up approach would require detailed energy sector information showing energy consumption at industry group or sector level. No information was readily available to support either approach. The bottom-up approach was, however, selected and supported by information from quick industry surveys and data from previous energy sector studies.

Some limited macro-economic analysis was carried out mainly to forecast energy demand, determine the activity levels in the various sectors of the economy and to build macro-economic scenarios.

Some Special Considerations, Assumptions and Analytical Boundaries for Zimbabwe

During the study it became apparent that there are certain assumptions, concepts and factors which while holding true and valid for developed countries in the assessment of abatement costs, are not applicable to Zimbabwe and perhaps to some other developing nations of similar standing. A few of these factors are discussed briefly below.

General Concepts and Reduction Targets

UNEP guidelines suggested assessing the cost of limiting emissions by 25% in the short term (2010) and 50% in the long term (2030) as

[2]UNEP Greenhouse Gas Abatement Costing Studies. Phase One Report. UNEP Collaborating Centre on Energy and Environment. Riso Denmark. August 1992.

[3]Ibid.

initial focal points which would be achieved if costs were reasonable. For Zimbabwe, reduction level of up to 21% in the short term and 39% in the long term were achieved.

A second concept governing the framework of analysis for the Zimbabwe study was the assumption that while a least cost option would be pursued, the element of cost should not constitute a limiting factor in selecting options since the cost of introducing reduction technologies would be the responsibility of an international fund put together for that purpose. This also serves as a simplifying assumption since it allows for the assessment of options without seeking to justify these against the complex issues of their impact on national welfare.

Local vs International Parameters

Under the UNEP guidelines it was assumed that a general down trend in international oil prices would prevail due to the effect of joint global efforts to improve energy efficiency in production. Some departure from this assumption had to be adopted for Zimbabwe with respect to the pricing of coal which is not traded on the international market and would, therefore, not benefit from the expected down-trend in global coal price. Coal price trends for Zimbabwean coal were, therefore, not linked to the global coal prices trend although some moderation in the rate of coal price increases was assumed.

The UNEP guidelines further suggested that the costs of abatement technologies should be based on factor cost. While this is a useful standard, it does not reflect the correct local cost of an abatement investment due to the fact that it excludes major distortions (which of course are why factor costs had to be used) in the cost of inputs as perceived by an investor and on the basis of which actual investment decisions are made. This argument aside, the Zimbabwe study adopted the factor cost approach in the hope that price distortions will be reduced in the future.

Analytical Models Used in the Zimbabwe Study

The above discussions relate to the analytical framework adopted in the study but the actual analysis had to be carried out using analytical models. The selection of these models had to take into account a number of factors including the nature and availability of data to be analysed, the output parameters of the models with respect to policy parameters of importance to local decision makers, the availability of skills to utilise the models and the time available to learn the models, and the time and cost of putting together data for the adopted models. The models considered would have required time and resources beyond the scope of the study both in terms of collecting the required data and learning time. For these reasons, the study developed a simple spreadsheet model perhaps akin to CEEM[4] and STAIR[5] used to assess CO_2 emissions reduction associated with each intervention and the cost of selected levels of reduction.

The model constructed in a spreadsheet allows bottom-up analysis of energy demand, emission level from energy utilisation and conversion and facilitates the calculation of abatement costs. These costs are broken down into fuel costs, capital costs, operation and maintenance costs. The primary reporting parameters are total cost of the abatement option and the unit cost measured as cost per tonne of CO_2 reduced through the introduction of the option. In general the assessment of cost does not include replacement analysis for existing polluting technologies as it is assumed that present investment is allowed to run for its full economic life and that abatement technologies are introduced at the tail-end of this life.

Box 1. Input and output parameters for the model are provided in specified columns in the box below:

Key input parameters	Key output parameters
• *Capital equipment* • *Equipment lifetime (years)* • *Levelised investment* • *Annual operation and maintenance levelised fuel costs* • *Discount rate %* • *GHG emission factor* *– by process* *– by fuel* • *Specific energy consumption* • *Annual activity level of option* • *Energy use efficiency*	• *Annual reference technology GHG emissions (tons)* • *Annual abatement option GHG emissions (tons)* • *GHG emission savings through abatement action* • *Emission reduction cost ($/tonne saved)* • *Cost allocation* *– capital cost* *– fuel cost* *– O&M cost*

[4]CEEM (CO_2 Emissions from Energy Consumption Module) was designed for assessing CO_2 emissions from the energy sector by OECD for IPCC.

[5]STAIR. A spreadsheet model designed at Lawrence Berkerly Laboratories to estimate sectoral end-use energy demand and primary energy supply.

The general analytical model supporting the above inputs and outputs is:

$$\text{Reduction cost} = \frac{(C_R + C_{MR}) + R_R - (C_A + C_{MA}) - R_A}{(E_R - E_A)}$$

Where:

- C_R = Investment for reference option
- E_R = Reference case emission
- C_{MR} = Reference case operating and maintenance costs
- E_A = Abatement option emissions
- C_A = Abatement options investment cost; other
- R_R = Reference option revenue
- C_{MA} = Abatement option operation and maintenance cost
- R_A = Other abatement option revenue

Reference Scenario and Reference Scenario Energy Demand

Energy demand calculated for the reference economic development scenario and reference scenario economic projections are shown in Table 1. Economic growth rates for the scenario are 4.6% per year for the short term and 3.8% for the period 2010–2030. The initial growth rate of 4.6% is based on official economic growth projections. The 3.8% allows for economic stabilisation in the long term and reflects growth losses in natural resource based industries such as mining and agriculture. An important consideration in project economic activity particularly on the basis of official forecasts is the ability of Government to steer the economy towards the desired or projected path. Even under conditions where resources are abundant this would be a difficult effort for any Government. For the Zimbabwe Government, the situation is made much worse by the occurrence of such constraints as the droughts which in many instances have managed to derail government plans and to draw resources from productive investment to social emergency programmes. Industry in Zimbabwe is very much linked to agricultural production which has strong forward and backward linkages with the former. Failures in agriculture due to drought or any other reason have an almost direct effect on the manufacturing sector but are felt much less in the mining sector.

By and large, however, it would be correct that in the absence of the natural disasters, the economy would pull through to expected growth levels.

At the bottom of this table is shown energy demand related to the reference scenario. While it is not expected that emission reduction interventions occur in this scenario, energy intensity of production is expected to decline in accordance with the Autonomous Energy Efficiency Improvement (AEEI) factors indicated in the far right column of the table for each economic subsector.

This factor is derived from the argument that even if a country does not introduce domestic energy efficiency improvement programmes, energy efficiency is bound to improve through efficiency improvements inherent in newer technologies available on the world market and which the country is bound to adopt. These are

Table 1. Reference economic development scenario and energy demand for reference scenario. (Exclude energy demand for residential sector) Economic data are in constant 1980 prices

	GDP in 1990[6]		GDP in 2010		GDP in 2030		
Constant 1980 Z$	mill. Z$	%	mill. Z$	%	mill. Z$	Growth rate 2010–2030	
Agriculture	548	12.42	1159	10.68	1722	2.00	
Mining	313	7.09	496	3.74	495	1.00	
Manufacturing	1101	24.94	3751	34.57	7043	3.20	
Total productive	1962	44.45	5316	48.99	9260		
Elect. & Water	156	3.53	484	4.46	719	2.00	
Transportation	262	5.94	739	6.81	1142	2.20	
Market service	840	19.03	2587	23.84	6864	5.00	
Non-market service	1194	27.05	1726	15.91	4581	5.00	
Total service	2034	46.08	4313	39.75	11444		
Total	4414	100.00	19851	100.01	22566		
Growth rate % pa 1990–2010			4.6			3.8	
Energy coefficient of performance (energy intensity of production)							
	TJ	TJ/mill. Z$	TJ	TJ/mill. Z$	TJ	TJ/mill. Z$	AEEI
Agriculture	27695	50.54	58568	50.54	87029	50.54	0.00
Mining	9748	31.14	10358	25.52	10566	21.34	1.00
Manufacturing	53856	48.92	150378	40.09	236045	33.51	1.00
Transportation	35843	136.81	87928	118.99	119843	104.95	0.70
Market service	5623	6.69	15672	6.06	38011	5.54	0.50
Non-market service	7992	6.69	10459	6.06	25368	5.54	0.50
Total service	13615	6.69	26131	6.06	63379	5.54	0.50

[6]Republic of Zimbabwe, Second Five Year National Development Plan, 1991–1995. Government Printers. December 1991.

non-price improvements which do not rely on local initiative. In view of the economic adjustment programme in the country, however, the effect of AEEI is negatively countered by short to medium term increases in activities within the energy intensive sectors and relative decline in the low energy service sectors. In the long run, the reverse is expected to prevail.

Further changes in energy efficiency are associated with changes in the structure of the economy shown in the table as % share of GDP held by each sector in a given GDP year: In the long term, it is expected for the service sectors to take a larger share of GDP than in the shorter term when the productive sectors predominate. This is a general pattern for most economies. Zimbabwe is expected to follow the same pattern.

Assessing Energy Demand in Households

Household energy demand was assessed for conventional and wood fuels.

The electricity projection for households were made in a household model giving the number of appliances per household, their unit energy consumption and the number of residential electricity consumers.

In order to make projections for domestic electricity consumption a household model was created with 3 consumer categories, low density metered (high income) and high density metered (low income) and high density load limited (without meter) supplies. Household appliance energy use for 1992 is summarised in Table 2.

Most of the high density households are on load limited supplies which run without meters but are designed to trip once the provided load is exceeded. These supplies allow only for the use of small appliances and lights.

The high electricity consumption in the low density households is attributable to the geyser, a water heating device common in high income households.

Household energy demand is assessed and projected on the basis of survey data obtained under this study and compared with data from previous surveys. Existing data indicated consumption levels of 12.5 kg fuelwood per household per day on the average with a range of 9–27 kg per household per day. Surveys carried out under this study showed a range of 9–30 kg per household in rural areas. For this study the average daily consumption of wood was chosen to be 15 kg in rural households and 5 kg in urban households. Population was used as the primary driver for wood-fuel demand. The use of wood in urban households is also driven by the urban household population but this is allowed to decline in intensity at a rate inverse to the diffusion of paraffin and electricity as higher grade fuels.

Present growth rates for rural households is 1.8% and that of urban households is 3.9% per annum[7]. These growth rates are adopted for both the abatement and reference scenarios.

CO_2 Emissions Assessment for the Reference Scenario

Base case CO_2 emissions were assessed from the reference economic and energy demand scenario described in the foregoing sections. These are presented in summary in Table 3.

The leading sources of CO_2 emissions are power generation, industry and transport. All emissions from power generation are associated with coal conversion to electricity. There is no use of liquid fuels for power generation except for boiler start-ups and flame stabilisation operations. Even in the reference scenario where no

Table 2. Household electricity consumption in 1992

1992 electricity consumption in kWh	Low density households	High density households	High density load limited households	Total domestic
Geyser	3500	0		
Hot plates	2190	2336		
Refrigerator	876	876		
Freezer	1095	0		
Lighting	964	197		
Ironing	110	110		
Heating	68	0		
TV	110	88		
Total	8911	3606	3320	
Number of consumers	102275	34092	131505	267871
Total consumption (kWh)	911	123	437	1471

[7]According to recent history of economic successes in the country, Zimbabwe unlike other African countries has maintained a consistent positive economic growth rate for the past 12 years.

interventions take place, the growth rate of CO_2 emissions is reduced from 5% per year in the short term to 3.8% per year for the long term.

Description of the Abatement Scenario

The construction of the abatement scenario involves introducing a set of abatement technologies. These are listed in the box below. Information in this box also includes diffusion rates for these technologies. It should be noted here that these diffusion rates represent first cut assessments by the study and may in some cases be rather ambitious. This can be said, for example, for the diffusion level for industrial boilers. Revised assessments are being carried out under a follow up study and will be published soon.

Emissions from the Abatement Scenario and the Abatement Cost Curve

Emissions from the abatement scenario represent emissions after the cumulative emissions reduction effect of a series of reduction technologies shown above. These emissions are shown in Table 4 alongside those from the reference scenario for comparison.

Table 3. Annual energy sector emissions of CO_2, 1990–2030-reference scenario (million tonnes)[8]

	1990 million tonnes CO_2	1990 % of total	2010 million tonnes CO_2	2010 % of total	2030 million tonnes CO_2	2030 % of total
Coal	13.41	82.2	26.27	80.3	47.92	83.50
Wood	0.00	0.0	0.00	0.0	0.00	0.00
Paraffin	0.24	1.5	0.46	1.4	0.80	1.40
LPG	0.02	0.1	0.02	0.0	0.02	0.00
Diesel	1.64	10.1	3.66	11.2	5.36	9.40
Petrol	0.74	4.6	1.64	5.0	2.36	4.10
Ethanol	0.00	0.0	0.00	0.0	0.00	0.00
AvGas	0.01	0.1	0.03	0.1	0.04	0.10
Jet A1	0.26	1.6	0.64	2.0	0.88	1.50
Total	16.32	100.00	32.73	100.00	57.37	100.00

Box 2. Listing of abatement technologies considered in the abatement scenario[9]

	Penetration 2010	Penetration 2030
Supply side technology—options		
Replace coal with hydropower	0 MW	540
Replace oil with coke oven gas in power station	1 plant	1 plant
Biogas digesters in rural households	7500 digesters	10,500 digesters
Increase afforestation	10,000 ha/year	10,000 ha/year
Central PV electricity	0 MW	200 MW
Demand side technology—options		
Install timers on domestic geyser	61,000 units	91,000 units
Install solar hot water geysers	61,000 units	91,000 units
Replace electric furnaces with coal furnaces in smelting	115 units, 2 MW	115 units, 2 MW
Replace electrolysis with coal gasification in ammonia production	1 plant	1 plant
Replace diesel with solar PV water pumping	1500 pumps	1500 pumps
Improve industrial boiler efficiency from 74 to 79%	675 boilers	2000 boilers
Improve power factor from 0.90 to 0.95	234 MVAR	854 MVAR
Introduce repayment meters for electricity	3000 meters	3000 meters
Introduce efficient tobacco barns from 5 to 1 kg coal/kg tobacco	320 barns	660 barns
Introduce zero tillage in agriculture	1245 tractors less	1245 tractors less
Energy conservation in industry	0 PJ	10 PJ
Introduce more efficient elec ric motors, increase from 60 to 75%	14,000 motors	61,000 motors

[8]UNEP Greenhouse Gas Abatement Costing Studies. Zimbabwe Country Study. Phase One Report. Southern Centre for Energy and Environment, Harare, Zimbabwe and Systems Analysis Department, Riso National Laboratory, Denmark. Department of Energy, Ministry of Transport and Energy, Zimbabwe. August 1992.

[9]Maya R.S., Muguti E., Fenhann J., Nziramasanga N., UNEP GHG Abatement Costing Studies: Zimbabwe Country Study Phase Two Report. Southern Centre for Energy and Environment, Harare/Riso National Laboratory, Denmark 1993.

Table 4. CO_2 emission from the energy sector in Zimbabwe[10]

Million tonnes CO_2	1990	2010	2030
Reference case	16.3	32.7	57.4
Abatement case	16.3	25.8	35.2
Reduction compared to reference case		21%	39%

Emissions savings from abatement activities are depicted in Fig. 1.

The introduction of the abatement technologies has associated costs. These are calculated using the models described earlier. The resulting cost curves were based on two discount rates with 10% being the base rate and 6% being introduced for sensitivity testing. The cost curve at the base rate is shown in Fig. 2 and the results of the sensitivity tests with a 6% discount rate are shown in Fig. 3. In this figure the sensitivity of cost to the discount rate is shown through the shifting of some of the technologies from one position on the curve to another. Overall, the curve is dominated by negative cost options

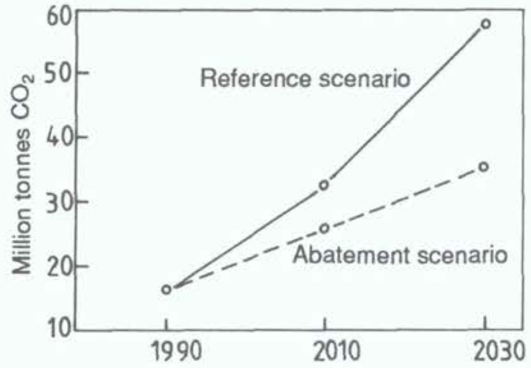


Fig. 1. CO_2 savings from abatement activities.

which are associated with demand side interventions. The total incremental cost of abatement activities defined as the sum of costs on the cost curve is Z$ 1,008 million in 2010 and Z$ 465 million in 2030. An alternative definition of total incremental costs is also possible and this is more meaningful for developing nations: It is the sum of all non-negative costs after implementing all non-negative costs options. The costs based on this definition are Z$ 1,282 in 2010 and Z$ 1,180 in 2030.

The negative cost options derive mostly from the selection of the baseline scenario which has high levels of efficiency improvement opportunities. A follow-up study presently being carried out by Southern Centre and Riso under UNEP Collaborating Centre on Energy and Environment seeks to identify barriers to the implementation of these no regrets options. It can be said beforehand, however, that the implementation of these options involves positive initial costs to overcome a series of inherent factors limiting the introduction of energy efficiency technologies in industry. These include assessment of and providing information on alternative efficient technologies, local and foreign capital for their acquisition, macro-economic

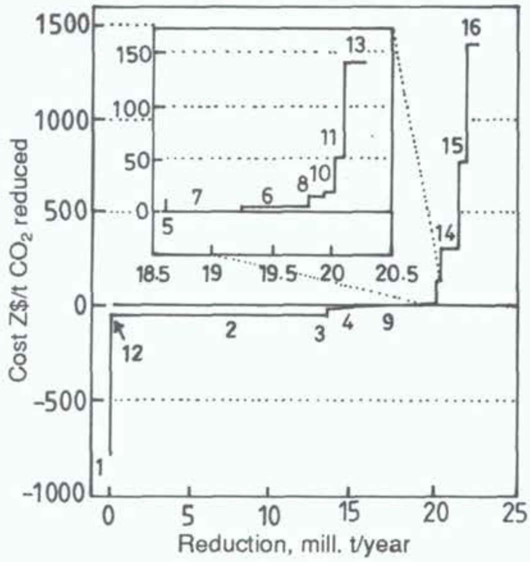
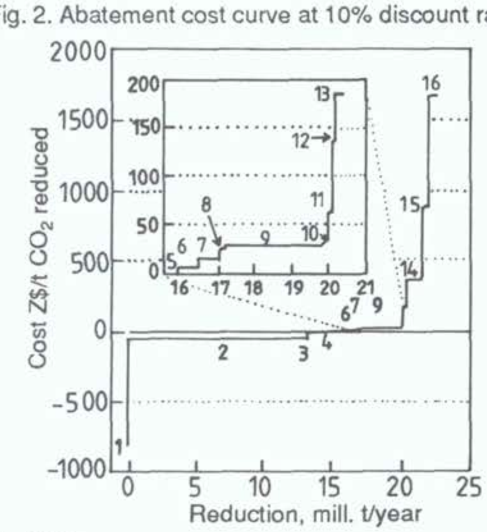


Fig. 2. Abatement cost curve at 10% discount rate.



1. Tillage
2. Efficient boilers
3. Efficient tobacco barn
4. Savings in industry
5. Repayment meters
6. Efficient motors
7. Power factor correction
8. Geyser timeswitches
9. Hydroelectricity
10. Biogas for domestic use
11. Afforestation
12. Coke oven gas for Hwankua
13. Solar geysers
14. Efficient furnaces
15. Central PV electricity
16. Coal for ammonia

Fig. 3. Abatement cost curve at 6% discount rate.

[10] Maya R.S., Muguti E., Fenhann J., Nziramasanga N., UNEP GHG Abatement Costing Studies: Zimbabwe Country Study Phase Two Report. Southern Centre for Energy and Environment, Harare/Riso National Laboratory, Denmark 1993.

distortions whereby inefficient producers are not penalised through loss of market, lack of definitive and enforceable inefficiency penalties in some sectors (the power sector already has penalties related to peak demand consumption for electricity).

The negative cost options in the cost curves, therefore, should serve as indicators for areas where investment may be targeted and not as a cut-off point for abatement cost funding.

Conclusions

The framework of analysis in abatement costing could differ significantly depending on whether it is applied in a developing or a developed country. While developed country interventions may be successfully instituted through regulations, penalties and incentives to induce industry to invest in favour of emissions reduction, developing country instruments for the same purpose are more likely to require active state intervention to support capital acquisition and to absorb the social implications of, say, making a transition from one fuel to another. This situation would manifest itself through the selection of discount rate where in developing countries, interventions are more likely to be based on public sector investment discount rates.

The use of global cost parameters may require special adjustments when applied to developing nations. This would be the case for oil prices, factor costs and other items whose use is justifiable in developed economies but could in themselves constitute a distortion if applied in developing nations. This could also be the case for tradeable and non-tradeable fuels such as wood and coal in Zimbabwe. Cost boundaries themselves, of course have different implications for developing vs developed nations. Narrowly defined cost boundaries fail to such investment and O&M cost exclude the important social cost associated with large scale interventions such as those required in the power sector.

The UNEP study was, however, aware of this situation in that it attempted to determine "the economic cost" of abatement activities. While such costs may have been assessed for other countries involved in the study, their assessment for Zimbabwe remained quite limited due to the lack of practical input/output models and input/output data for the economy. Despite this limitation, however, useful descriptive and sector specific assessments were made and provided a sound basis for deriving practical abatement levels and related costs.

The dominance of negative cost options in the Zimbabwe case may be a misleading result of the study since even the so called negative cost options require positive investment to initiate.

An additional useful outcome of the study was the identification of issues to be further analysed in the interest of instituting abatement options generated in the study. These issues include assessing the internal consistency of macro-economic projections, assessing present barriers to the implementation of negative cost options and identifying potential measures for overcoming them, and identifying joint products from abatement activities for use in developing alternative ranking criteria for abatement options.

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Discussant's Comments

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Introduction

Literature on equity and social considerations is value-loaded because the subject encompasses welfare issues. Welfare concerns focus on who gets what where and how in an equitable manner. Besides the dictates of the bio-physical environment on the spatial pattern of resources endowment, of which climate change is instrumental, access to resources is largely a matter of practical politics. This realisation reinforces the need for national and international cooperation in creating an enabling environment for equitable distribution of resources for the present and future prosperity.

Social Issues for Consideration

Drewnowski (1974) implicitly considers human well-being as having two concepts which he designates as (i) a passive aspect which refers to what a population receives and, (ii) what a population can give in consequence of their state.

Welfare concerns should therefore embrace what people get and what they give in an equitable manner. This approach in sharing the national cake transcends the simplistic view of consumption in economic growth, argues Smith (1977, p. 39).

The concept of equity in the allocation of societal benefits and costs in relation to public spending has, therefore, become a major issue of social concern. Ideally, complete equity is unattainable because of intervening environmental factors relating to absolute and relative distance which are exacerbated by unequal distribution of power resources.

Proponents of social inequality in the allocation of resources, therefore, argue that inequality is justifiable if criteria for determining equity is based on the following factors as listed by Smith (1977, p. 125).

- Local factor endowment (resource potentials),
- Productive factors (skilled and unskilled labour, efficiency and technological input),
- existence of discriminatory laws and practices.

The designated factors determine the nature of social contribution to the existence of public policy which should provide checks and balances against inequality in resource allocation.

Social considerations, therefore, aim at ameliorating inequality in resources utilisation by emphasising equity in access and utilisation of resources by focusing on societal issues such as health, education, housing, cultural heritage, poverty and hunger (nutrition), personal security and administration of justice, physical environmental state in relation to pollution, resource exploitation, social opportunities for occupation and income, urban crisis and so on as listed by OECD (1973).

Attainment of the designated social goals is increasingly being jeopardised by climate changes on the one hand and inequality in power resources or practical politics on the other hand. Climate changes as reflected by past and present models and reinforced by simulation models portraying future scenarios suggest that Africa and other tropical continents face a dismal future. IGBP (1991) suggests that availability of resources and equitable distribution of such resources will be constrained by the following factors linked to various conditions of climate changes:

- determination of human health and welfare through drought, famine, dust storms and floodings,
- loss of natural biological resources affecting supply of food, fodder, medicinal plants (drugs), industrial products and so on,
- atmospheric pollutants creating health hazards through increased respiratory diseases in humans,
- land-use changes will affect agriculture, industrial energy production,
- desertification and deforestation will increase as marginal ecosystems expand,
- water resources (river basins, inland lakes and coastal systems) will experience increased sedimentation and siltation of dams. All these will affect coastal fishing and tourism.

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In addition to these environmental effects of climate changes, we need to emphasise that human migrations resulting from displaced persons will exacerbate the problem of national and international refugees. Increased rural migrants seeking refuge in urban centres will render current urban crises more grave. The intensity of these environmental problems will vary within and between nations but will require international cooperation for equitable allocation of resources.

Conclusion

Equity at the national level could be enhanced through international cooperation in evolving common approach (stance) in tackling issues of societal concerns. One important area of cooperation is the area of research and networking in the exchange of relevant data for formulation of appropriate policies on the environment and devising appropriate laws and regulations that are implementable. International collaboration in research could assist in developing new crop strains and agricultural management practices that are adaptable to changes in climate. Use of appropriate technologies in marginal areas may require new skills and large funding which majority of developing countries cannot realise without external assistance.

There is also need for the development of an effective social welfare security system in developing countries where over 80% of the populace eke a living from agriculture. In addition, such countries need to repeal obnoxious laws and regulations which hinder free flow of human resources, goods and services within their national boundaries. Emphasis should be on programmes that enhance the well-being of disadvantaged members of the society to improve their access to health, education, food, housing and shelter. Such programmes need collaboration between the government, non-governmental organisations and the private sector.

Another area of concern should be on normal sources of conflicts between various social classes. This may require mass education of the populace on basic democratic rights, constitution and other laws and regulations that enhance environmental health.

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Discussant's Comments

International Environmental Policy: Equity Considerations

BRIGHT E. OKOGU*

Introduction

The issue of climate change is a truly global phenomenon; not only is the atmospheric concentration of greenhouse gases affected by the action of everyone, it also has consequences for everyone. However, the contribution of individual countries to the problem is different, just as the impact of a global warming process is expected to be different. For example, small island countries and coastal communities are more at risk from flash floods and other extreme events traceable to global warming than their counterparts in the hinterland, irrespective of whether their level of greenhouse gas emissions may be only minor. Another dimension of the differential impact comes from the possibility that such countries may be less equipped, in terms of institutional capacity, to deal with the consequences of climate change. Further, an increase in atmospheric carbon dioxide (CO_2) and an increase in temperature may well favour agriculture in some of the countries in the Northern hemisphere (typically responsible for more emissions) while having a debilitating effect on agriculture and water resources in the tropics. Clearly, there are issues of a global commons (global environment) and externality (GHG emissions from some countries which affect others negatively). The work of the Intergovernmental Panel on Climate Change (IPCC) and the signing of the Rio Treaty are a testimony to the urgency of, and concern for the problem. There is a desire to solve a perceived common problem facing mankind.

Not surprisingly, serious issues of equity arise when fashioning policies to deal with a problem of such global character. There are entrenched, usually conflicting interests on all sides, compounded by the fact that the parties involved in the process are of unequal strengths. The policy proposals on climate change which have emerged so far range from carbon taxation (e.g. the EU carbon/energy tax) to regulations (product specification, zero emission vehicles, etc). These have attracted criticism from affected countries and industries which feel a certain sense of inequity in these policies. These inequities usually centre around whether competing fuels or industries are subject to similar conditions. In the case of countries, such as net oil exporters, the grouse is that their product is unfairly targeted for excessive taxation, and not really for the sake of improving the global environment, but as a means of raising of revenue for the treasuries of consuming countries. A further area of conflict comes from the fact that initial conditions are different for different countries; poorer or Less Developed Countries (LDCs) are less likely to rank a clean environment as high as their rich, industrialised counterparts in their order of priorities.

Given the global nature of the climate change issue, policies not only need to be fair, but also seen to be so. Unilateral policies in one part of the world can very easily be negated by a contrary action in another group of countries. For example, LDCs have recently crossed the 50% mark in the global share of GHG emissions. This paper examines some of the climate change policies from the point of view of equity, and goes on to propose measures to improve the existing set-up. The solution to the problem must aim to have the support of the widest possible international coalition. It must aim for a win-win solution.

Concepts of Equity

The concept of equity touches on issues of fairness, equality and justice, according to natural law, in the distribution of resources and responsibilities. In the context of global climate change, it implies an equitable allocation of emission rights to contemporaneous citizens of the world, either as individuals or as collectives (e.g. nations). It can also mean an allocation of

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the *same* rights between different generations of people. This intra- and inter-generational aspects of equity are at the core of the challenge in devising generally-acceptable international environmental policies. It will be recalled that in the run-up to the Earth Summit in Rio, a number of industrial countries such as Japan and Australia announced carbon-reduction plans which were conditional on other industrial countries doing the same. Similarly, a number of European industries resisted planned increases in energy tax for fear of losing competitiveness, on grounds that their counterparts in other parts of the world were not subject to similar taxes. These reflected intra-generational aspects of the problem.

Inter-generational dimensions, on the other hand, usually take the form of differential rates of discount by different countries for future streams of environmental benefits. They reflect the relative values put on current consumption of environmental capital as compared to its consumption at a future date (by succeeding generations). An important element of intertemporal choice by different societies is the level of their current income. In general, a poor country, *ceteris paribus*, is expected to have a higher rate of discount than a richer country. This was well articulated by Fisher (1930) when he stated thus: "A small income, other things being equal, tends to produce a high rate of impatience...". He adds aptly that such a behaviour could be explained by the fact that the individual needs to survive the present if there is to be a future. Consequently, from an environmental point of view, LDCs will tend to behave as though they place a higher stock on present usage of environmental capital than their industrial counterparts.[1] In an earlier work, we had identified a number of factors that are likely to be important determinants of the discount rate for the environment (Okogu, 1993). These include permanent income, stage of development, net foreign debt/external reserves and availability of indigenous "clean" fuels. It was also shown in that paper that a clean environment being a normal good, LDCs will demand more of it, as with other goods if their income level rises.

Neo-classical economic theory, does not have very much to say on the question of equity; indeed, it is not handled very well given the fact that it has normative aspects. Different people place different values on equity; what appears fair to one group may be frivolous to another. The dominant paradigm in economic theory is global utility maximisation, with less attention paid to distributional aspects. Thus, a policy change is said to be Pareto superior, compared to the *status quo*, if it results in a gain for at least one person without making anyone else worse off. This utilitarian approach reflects the three cardinal characteristics identified by Sen (1987) as the basis for judging the goodness, or otherwise, of a policy. These are (i) that only utility has an intrinsic value, (ii) only the total value of utility matters, and not its distribution (iii) any action that contributes to the fulfilment of wants, even if such action is morally repugnant to some people, is considered to be right in the sense that it contributes to an increase in total utility.

Obviously, this theoretical construct is at odds with the notion of equity; utilitarianism does not assign intrinsic value to fairness or justice unless it results (as is rarely the case) in an increase in total utility. The application of utilitarian principles to climate change issues would certainly compound existing intra-generational inequity, as it would assign more environmental resources to those that are already well-off. In a similar vein, if it is applied to inter-generational distribution of environmental resources, future generations are likely to be short-changed because the present generation will have to make a choice for future generations whose needs and preferences are unknown. Even if one were to assume that the present generation cares about the welfare of future generations (altruistic or bequest characteristics), the chances of getting it right will still be minimal. Rawls (1971) tried to improve on the utilitarian theory by introducing elements of justice into the framework. In his approach, equality of rights and opportunities is assigned an intrinsic value in a way that utilitarianism does not. Under the theory, individual positions in the global society are assumed to follow a random distribution and no one knows his exact station. When this "fair die" is cast, everyone has an equal chance of landing in the most advantaged and disadvantaged rungs of the social ladder. One of the relevant conclusions from Rawls' theory is that rational, risk averse, individuals will take decisions which they would not regret once the "veil of ignorance" under which they operated is lifted. Although not without drawbacks, Rawls' position would appear to be more appropriate to the question of climate change (certainly the theme of this workshop), as it forces everyone to place himself in the position of others.

The application of equity considerations in international environmental policy can be examined under different categories, including the allocation of emission rights between contemporary citizens of the world; the sharing of clean-up responsibilities between states; and the inter-fuel incidence of taxation. We shall

[1] In reality, this is not really the case. The higher valuation of present consumption vis-a-vis a future clean environment merely reflects the need for surviving the present. These countries care for a clean environment and the welfare of their descendants as much as any other country. Given their small contribution to the emission problem, they and future generations can be said to be fellow victims of a potential climate change.

examine the climate change issue under these and related criteria. We do not dwell much on inter-generational aspects of equity partly because it is covered in other papers, and partly because reaching agreement on intra-generational equity is a prerequisite for a similar agreement on the welfare of future generations. First, however, we look at the present state of world GHG emissions.

In reality, this is not really the case. The higher valuation of present consumption vis-a-vis a future clean environment merely reflects the need for surviving the present. These countries care for a clean environment and the welfare of their descendants as much as any other country. Given their small contribution to the emission problem, they and future generations can be said to be fellow victims of a potential climate change.

Structure of World Emissions of Greenhouse Gases

The pattern of GHG emissions, measured on a per-capita basis, closely reflects the stage of economic development in different countries. Industrial countries, not surprisingly, dominate the emissions league table in line with their high production and consumption processes. They are followed by the Newly Industrialising Countries (NICs), and finally the LDCs a long way behind. Of course, the figures do not indicate a strict proportionality to any index of development (e.g. income) because of differential energy efficiency levels, the energy-mix etc. Thus Japan's per capita emissions of carbon are less than half those of the United States, which is very different from the ratio of income per head in both countries—a reflection of the high efficiency level in the former country. Similarly, France has a lower emission per capita than either Germany, or the UK, reflecting the high proportion of French electricity generated from nuclear power, as compared to most of its European partners with a high dependency on coal-fired utilities. Table 1 shows the structure of GHG emissions for 1992.

It is obvious from the table that the present profile of the use of global environmental resources among countries is not equitable by most common definitions of the term. The average person living in the OECD region emits 5.5 and 10.42 tons of carbon per year (t-c/y) respectively for every 1 t-c/y emitted by their counterparts living in Latin America and Africa. Since carbon emissions have a direct link to production activities, it is obvious that industrial countries are drawing on a *common* global resource and generating income from it, far in excess of their entitlement, assuming equitable allocation. The data on atmospheric concentration of carbon show that it has more than tripled between 1860 and 1990, having risen from about 60 Giga Tonnes of Carbon (GTC) to about 200 GTC. This has closely tracked the growth of industrial production over the same period.

Although it is true that most of the emissions prior to the second world war have been largely absorbed by the natural eco-system, and that most of today's concern relates to emissions since that time, the fact remains that industrialised countries are still responsible for most of the problem. Equity considerations—the theme of the present IPCC workshop—dictate the need for a fairer system of allocation of environmental capital. This is absolutely necessary if a global environmental policy is to emerge which will have the backing of most of the world. Anything short of this will very likely be ineffective and unsustainable as developing countries, from where most of the incremental emissions are expected, may be unable to play their part in emission-limitation strategies. They could argue, with some justification, that they have a right to develop (and emit carbon) just as the present industrialised countries did a long time ago. It is a challenge to the international community to devise innovative policies towards realising the

Table 1. World emissions of carbon by country/region, 1992

Country/ Region	Oil (mill. tons)	Coal (mill. tons)	Gas (mill. tons)	Total (mill. tons)	% share	Emissions per capita (tons)
World	2627	2274	1067	5968	100	1.10
OECD	1461	954	518	2932	49	3.44
USA	575	481	38	1341	22	5.25
Japan	220	69	30	320	5	2.57
Germany	116	103	35	254	4	3.15
OECD-Europe	532	326	156	1042	17	2.87
FSU	280	262	327	868	15	3.06
China	113	558	8	678	11	0.58
Africa	93	99	24	216	4	0.33
Rest Asia	264	221	45	530	9	0.26
L. America	214	25	47	286	5	0.63
M. East	155	5	60	221	4	1.59

Sources: (i) *International Energy Outlook* 1994, USDOE, Energy Information Administration.
(ii) Hargreaves D., Eden-Green M. and Devaney J., *World Index of Resources and Population*. Dartmouth, Aldershot.

dual goals of economic development and maintaining environmental integrity. This is the essence of sustainable development.

The Present State of International Environmental Policy

Following the signing of the Framework Convention on Climate Change in Rio in 1992, the disparate policies of different industrial countries, which had been in the form of statements of intent on GHG emission reductions took on a clearer, more uniform outlook. This could be summarised as the policy, by most of them, to reduce carbon emissions to the 1990 level by year 2000.[2] Developing countries were exempt at the initial stage on grounds of "present needs and special circumstances". Nothing concrete was said about the policy beyond 2000[3], which opens up a lot of possibilities, including an extension of the present regime, inclusion of some of today's LDCs in the emission-reduction programme, etc. The climate change policies of the USA, the European Union and Japan are examined below, followed by a brief assessment of their perceived chances of meeting the emission targets. We also briefly highlight the policies of some other OECD countries.

The USA

Apart from the Clean Air Act of 1970 and the Amendment to it in 1990, the relevant US policy on the environment is the *Climate Change Action Plan*, unveiled in October, 1993. Under the plan, greenhouse gas emissions are to be reduced to the 1990 level by 2000. This was a major departure from the position of the previous administration which did not specify a target. A key feature of the Plan is that it focuses not only on carbon, but also on other GHGs such as methane, nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs), with each gas being weighted according to its global warming potential in relation to carbon dioxide. The programme involves supply- and demand-side policies, with the former involving greater production and use of natural gas and greater efficiency in the generation, transmission and distribution of electricity, while the latter set of policies would focus on efficiency improvements at the end-user point. The Plan also envisages an increase in reforestation programmes and a reduction in pulpwood demand. It is estimated that GHG emissions, in carbon equivalent, would be reduced to the 1990 level in 2000.

A recent assessment by the Energy Information Administration (EIA)[4] indicates that CO_2 emissions are rising well above the levels assumed under the climate change action plan. Energy-related CO_2 emissions were supposed to rise from 1338 million metric tonnes of carbon (mmtc) in 1990 to 1384 mmtc in 1998, and then decline slightly to 1379 mmtc in 2000. This would still be above the 1990 level, but increased carbon sequestration was expected to bring total GHG emissions to about 3 mmtc below the 1990 levels. However, the EIA data indicate that energy-related carbon emissions at the end of 1993 were already higher than the 1990 level by about 2.6%—a level that should not have been reached before 1996 under the plan.

The European Union

The centre-piece of the EU environmental policy is the yet-to-be-adopted carbon/energy tax under which a 50:50 tax weighting is to be assigned to all energy carriers. The tax was to start at $3 per barrel of oil equivalent beginning in 1993, and rising to a limit of $10/bn by 2000. There was the proviso that should there be a fall in the price of oil, the whole tax would be imposed in one fell swoop. An amendment was subsequently agreed to the effect that the tax will start from 1995 but at a higher base, as a result of the delay in the introduction of the tax. In addition to this, there were supposed to be other measures to encourage energy efficiency as well as the development, testing and popularisation of new energy-saving technologies under the *Thermie* programmes. The four poorest members of the Union—Greece, Ireland, Portugal and Spain—were allowed to delay the adoption of the policy until they reached 50% of the increase in GHG emissions projected by themselves for the year 2000. Another aspect of the tax concerned the dichotomy between coal and nuclear lobbies in relation to the 50:50 weighting. While the coal interests argued for a pure energy tax, stressing the employment contribution of the industry, the nuclear industry, championed by France, favoured a pure carbon tax. Further, because of the very nature of the EU, being a collection of sovereign states, individual members have adopted their own energy and environmental programmes which are of varying degrees of stringency.

As a result of the fact that a lot of disagreements have remained unresolved, there has been a delay in the adoption of a coherent EU policy in this area. Even so, the individual policies of these countries were recently assessed by the EU commission based on the climate change plans of member countries. Their conclusion was that there is no guarantee that the emission targets

[2]The base year differs for a few of them, such as Germany and Denmark respectively, which use 1987 and 1988 as reference points.

[3]Again, a few countries like Austria and Germany have a commitment to reduce emissions by a certain amount, compared to their base year levels, by 2005.

[4]Reported in *The Energy Report*, Vol. 22, No. 16 (25 April 1994).

would be fulfilled because many of the plans are not specific enough in terms of their environmental objectives. It thus recommended that community-wide policies should be encouraged.

Japan

Japan has committed itself to stabilising CO_2 emissions at the 1990 level by the year 2000 under an environmental change action plan. An important feature of the plan is that the stabilisation be on a *per capita* basis, and on the condition that its major trading partners adopted the same or equivalent policies. The strategy is to achieve efficiency improvements through technological innovations. In furtherance of this, the country launched a comprehensive efficiency programme in late 1992, including setting targets for industry. Under the programme, tax incentives and low-interest loans are to be offered for environmentally-efficient technological developments. Besides, Japan has taken steps recently to diversify its energy supply source by building a fast-breeder reactor (named *Monju*). Before this, Japan had some 45 conventional light-water nuclear plants which, together, supply about 30% of the country's power requirements.

A recent government assessment report, however, casts doubt on the chances of Japan achieving its stated target. It was noted that in spite of the recent recession which the country has experienced, its energy demand has continued to grow. The original demand forecasts, on which the emission projection was based, assumed that energy demand would grow by about 1.5% per annum. However, according to the report, demand in some sectors of the economy, like the residential sector, are growing at a much faster rate (3% in this case). With this as background, it would appear that Japan will have difficulty meeting its target, especially when the economy returns to growth path. An interesting question arises at this stage, namely whether the perception that Japan's main trading partners are not on track to meet their emission targets might persuade it to try less hard. After all, Japan is the most energy-efficient of all OECD countries, and it may argue that others should catch up with it first before it takes further steps.

Other OECD

The policy situation in other OECD countries is quite varied, but countries like Finland, Norway, Sweden, Switzerland and Austria have been quite active on the environmental front. The Swiss government, for example, recently got approval for a Euro-compatible VAT system in a national referendum. This involves a tax rate of 6.5% applied to all energy carriers, as well as an unspecified "special tax" under which it is believed that the government would impose an extra tax equivalent to the EU carbon/energy tax whenever this becomes operational. Given the delay with the EU tax, it was decided that the tax, to be based on GHG emissions rather than on energy, would now take effect from January 1996. It will be introduced in three stages, reaching a peak of SF36/tonne of CO_2 by 2000. Energy-intensive industries are to be partially reimbursed to ensure they remain competitive. Switzerland has an interim target of stabilising its carbon emissions at the 1990 level by 2000, and to reduce them after that date. Finland has a climate change programme under which petroleum taxes have been increased since 1 January 1994. It is somewhat similar to the proposed EU tax, in the sense that part of the tax (60%) is carbon-related. Norway has a commitment to stabilise carbon emissions at the 1989 level by 2000, and in this respect, has introduced a "special CO_2 tax" since 1991. Australia and New Zealand have policies to stabilise emissions at 1988 and 1990 levels respectively by 2000, but conditional on "no-regrets" measures, and similar policies by other industrial countries.

Aside from the specific issue of difficulties in meeting the emissions targets, the question needs be asked whether environmental policies in the major consuming countries are equitable, or even efficient from the point of view of reducing the GHG emissions. Table 2 below gives a comparative analysis of energy taxes on coal, oil and gas in the USA, the EU and Japan. It gives a broad outline of the relative taxes on fossil fuels. Petroleum products are taxed *at an average rate* of up to 11 times the rate on coal

Table 2. Fuel tax rate in major OECD countries (1983, 1993)

	1983	1993
USA		
Coal	N/A	N/A
Oil	16%	31%
Gas	N/A	N/A
European Union		
Coal	0–16%*	0–16%*
Oil	34%	61%
Gas	N/A	0–8.5%
Japan		
Coal	N/A	2.9%
Oil	18%	33%
Gas	0.7–0.9%	2.8–2.9%

* The average EU tax on coal is actually around 3%. Most of them have zero taxes on coal or subsidise it. Only a handful, including Belgium (11% tax), Denmark (12.1%), France (16%) and the Netherlands (16%) have any tax on coal, mostly on steam coal for industry and/or household sectors. Even then, as in the case of Denmark which introduced these taxes only in May 1992, 50% of the tax is refunded.

Sources: (i) IEA: *Energy Prices and Taxes of OECD Countries*, IQ 1994 (ii) OPEC.

in Japan; and about 20 times the rate in Europe[5]. This represents another dimension of the inequity in international environmental policy. Net oil exporters have consistently argued that their principal export good is unfairly targeted to bear the brunt of emission reduction. To butress their point, they point out that coal, which is more carbon-intensive, is not only taxed relatively lightly, but is actually subsidised in a number of OECD countries. The environmental benefits of phasing out coal subsidies have been studied (see, e.g., Okogu and Birol, 1992, 1993); and also of its distortionary effects (Radetzki, 1994).

Of course, there are issues of domestic economic policy, including employment and the need for self-sufficiency which may explain the favouring of the coal sector, but this is a separate matter entirely. The reality is that the playing field is not level, and it is a major source of dissatisfaction among oil exporters. Besides, from an environmental point of view, the tax structure is not carbon-efficient, and is perceived to be driven by fiscal considerations than a real desire to reduce emissions.

An immediate manifestation of the tax structure can be seen in the fact that the per-barrel tax income accruing to major consuming countries are many times the revenue earned by oil exporters. For example, for every dollar earned by an oil exporter in the form of crude oil sales in 1992, the German treasury earned \$3.27; Denmark got \$4.56; and Italy earned \$4.82. Taxes of the type being proposed by the EU will have dramatic redistributional consequences, as more of the oil rent will be transfered to major consuming countries. Our estimates indicate that an EU-type carbon/energy tax, imposed now over and above the existing tax regime will result in a loss of revenues for OPEC up to the tune of a cumulative amount of \$66.5 bn (1993) by 2000; \$353.9 bn in 2010; and \$1045 bn in 2020 compared to base case. A point worth repeating is that these countries are themselves developing countries and are a good distance from being industrialised. Like everybody else, they also want a clean environment for themselves and their descendants, but they want this to be achieved in a manner that is fair to themselves and others. They have legitimate concerns which, surely, an equitable international policy on the environment would want to take account of.

Equitable Environmental Policy

In the light of the above, it is evident that a better definition and coordination of policies will be needed in order to widen the support base of the existing policies. This is essential if the world is to make an impact on the carbon emissions problem. The Annex-1 countries alone cannot solve the problem, and this brings one to the role of LDCs. Even if it is not feasible for them to cut emissions at this stage, steps could be taken so that they are assisted to follow a less carbon-intensive path to development than the present industrialised countries did. There could be grave consequences for the environment if policies are not properly coordinated. Firstly, the emission-reduction efforts of Annex-1 countries could be negated by a non-supportive set of policies in non-Annex 1 countries. A foretaste of this possibility can be glimpsed from a recent report by the Energy Information Administration (EIA) which indicated that the LDCs in 1992 accounted for 48% of energy consumption and 52% of emissions, as compared to 39% and 43% respectively in 1970. Policies that could accentuate this trend include wrong energy pricing (Burgess, 1990; Shah and Larsen, 1992; Larsen and Shah, 1992), choice of fuels, population growth, etc. Further, there is a real possibility of "dirty" industries migrating to non-Annex 1 countries if their environmental rules are less stringent. This could then conceivably raise new complications for world trade regarding the "greenness" of traded goods. Under such a scenario, the temptation to use trade sanctions to enforce poorly-conceived environmental policies cannot be ruled out. Such a development, which has been warned against by, among others, Whalley (1991), can only complicate the problems of GATT/WTO. What is needed is a set of policies that will command the confidence of a large number of countries. One way to do this is by developing areas of cooperation, such as environmentally-relevant technology transfer, addressing questions of debt, poverty and development, etc. Some of these elements which are receiving less attention today in the debate, were emphasised in the Brundtland Commission report (1987) as an integral part of a sustainable common future.

Other areas of importance include the much talked-about Joint Implementation (JI) programme, although it must be emphasised that extreme care is needed in crafting the details of this policy if its benefits are to be maximised. Good projects in the country of implementation must be carefully identified, and costing must be seen to be fair. Further the party financing the project must not then become lax in its other efforts at emission-reduction just because it has "paid" for an emission-reduction project elsewhere. In principle, a system of

[5]This is calculated on the basis of the 3% average rate for the whole of the EU. Although the US data on coal tax are not available, all indications are that it is also quite marginal.

appropriate project costing could guard against this. Related to this is the issue of initial allocation of emission rights and clean-up responsibilities. The guiding principle here, too, must be equity. One possible area of JI cooperation, for example, is in gas-flaring during oil production. Data from CDIAC (1991) show that in 1989, gas-flaring accounted for 3% of total CO_2 emissions in Latin America, 3.5% in the Middle East and 7% in Africa. The proportions are a lot more significant if the emissions from this source are related to the total emissions of the few individual countries in these regions responsible for them. Finally, a move from the present skewed structure of inter-fuel taxes to a more level playing field would not only be more carbon-efficient, but would also bring more countries on board.

Conclusions

The theme of this IPCC workshop is equity and social considerations in climate change policy. Given the global nature of the problem at hand, it should be at the heart of the discussions not only because it is a principle which appeals to the better aspects of human nature, but also because of the practical need to build the widest possible international coalition for the common project. Without a perception that it is fair, the policy is unlikely to succeed. The present pattern of emissions presents a very skewed picture, with industrial countries being responsible for most of them. In contrast, the effects of a climate change will affect all mankind. LDCs, especially coastal and island communities, could suffer disproportionately not only because of their geographical location, but also because of their limited institutional capacity to cope with extreme events. This paper has examined existing policies from the point of view of equity, with the conclusion that they are not capable of garnering a very wide support base. Besides, some of them are outright inefficient from an environmental point of view. Some proposals for a way forward were also suggested. There is a need for genuine international environmental dialogue because only through cooperative efforts can the threat of global warming and the worst effects of climate change be averted.

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Discussant's Comments

Equity Considerations Among Countries

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Climate change caused by the greenhouse effect is the result in the course of industrialisation of developed countries over the long period of more than one century. The current high level of living standards and physical civilisation in most developed countries have been achieved at the expense of the deterioration of environment upon which the existence of all human beings in both developed and developing countries depends. This must be recognised as a common ground in discussing the equity considerations among countries. This leads to the issues of differentiated responsibilities of countries, intergenerational responsibilities between the current and the past, the current and future generations, lead actions taken by the developed countries to deal with the climate change issue, etc.

Historic analysis of the responsibilities for the climate change issue is not enough in looking forward to the further development of the developed, and the urgent need for developing the economy of the developing countries. It is vital for the developing countries to rapidly develop their economies in order to satisfy the basic needs of life. Development is the top priority for the majority of the people who are still living in poverty. The rapid development of the economy of the developing world will inevitably exert further pressure on the environment.

A sustainable way of developing economy, therefore, would be the solution to the dilemma of handling the twin issues—development and environment. This calls for a series of strategies and policies for development, including:

- *The control of population growth.*
- *The environmentally sound technologies to be used in developing economy.*
- *The technological and financial cooperation on a global scale, in particular, the technology transfer and financial assistance from developed countries to developing countries.*
- *The gradual change of energy structure from the current dominance by fossil-fuels to the future dependence on renewable and clean energy resources.*
- *The improvement of efficiency in the process of production, conversion, transmission, distribution and use of energy.*

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Discussant's Comments

Some Reflections on Climate Change: Equity Among Nations

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Growing scientific evidence points out to the occurrence of enhanced greenhouse effect leading to the earth being warmer than it would otherwise be without the effect. In appreciation of the consequences of that phenomenon, which to a large extent is a result of human activity, nations of the world have signed the United Nations Framework Convention on Climate Change (UNFCCC) which outlines steps that need to be taken in order to reduce present and future emissions of greenhouse gases due to human activity.

Anthropogenic greenhouse gas emissions have by and large been the result of industrialisation which started much earlier in developed countries. That these countries are responsible, to a great extent, for the enhanced greenhouse effect is now a matter-of-fact. The UNFCCC has recognised this "inequity" in the contribution of the Parties to global warming and appropriately refers to the responsibilities of all Parties, developed country Parties, developing country Parties and Parties undergoing the process of transition to a market economy. There is an implicit admission in the UNFCCC that developed countries have to bear much of the cost of stabilising global anthropogenic greenhouse gas emissions perhaps not so much because of their contribution but rather because these countries have strong economies which can support activities to stabilise greenhouse gas emissions in their own countries and also support efforts of developing countries towards the same endeavour. The issue of equity among countries in relation to climate change can therefore be looked at from the point of view of contribution to emissions, responsibility and ways and means to stabilise the emissions and the economic divide between the developed and developing countries.

The UNFCCC commits developed country Parties to assist developing countries in meeting some costs related to meeting their obligations under the Convention; the use of the word "some" is deliberate. It is added to illustrate the difference of perceptions among countries on such concepts as "incremental costs" which are allowable costs in terms of criteria to qualify for compensation in mitigation projects. Reference is made to the provision of resources for the transfer of technology. Financial mechanisms agreed upon to effect resource transfer can/should be seen in a broad context of the need to help developing countries evolve sustainable development strategies, strategies which will make developing countries capable of meeting, to a large extent, the challenges posed by climate change. The issue of equity therefore goes beyond emissions and mitigation. It covers a spectrum of structures and practices that exacerbate the inequity among nations in respect of development in general and responses to climate change in particular. Things like inequitable terms of trade, the debt crisis and lack of a capacity for technology assessment, assimilation and development affect developing countries negatively in responding to climate change.

By way of summing up, equity among nations in respect of climate change has been considered from the following viewpoints:

- the role of developed countries in anthropogenic greenhouse gases emissions;
- the inability of developing countries to mitigate the emissions;
- the vulnerability of developing countries to climate change and the limited capacity to adapt;
- the need for equitable global relations including trade, debt, etc.; and
- poverty alleviation.

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Discussant's Comments

Transcending Institutional Filters

DIPAK GYAWALI*

This session witnessed active participation from the floor which brought forth a variety of perspectives, often diametrically different, on the same issue.

From the perspective of social science, this is as it should be: The social universe is pluralistic, even within countries and quite naturally between countries. My comments stem from the Grid/ Group analysis method of Cultural Theory which basically asserts that perspectives arise from how social groups are defined along the two parameters of grid ascription and group control. They give rise to four mutually exclusive social environments: that of the hierarchists who are critical but risk averse, strive to retain control and believe that nature is manipulable within the hierarchies regime; that of the egalitarians who are less concerned with practicality and more with maintaining a millennial vision, and employ a strategy of alarm to penetrate the institutional filters of the hierarchy; that of the individualists that subscribe to no group and accept no external order; and finally the fatalist masses who can only cope with whatever comes.

From a cultural theory perspective, the presentation of Aubrey Meyer represents an egalitarian view which includes that the First World should structurally adjust and reduce its consumption of resources. Richard Bradley's presentation represents the hierarchic view which seems to reach a diametrically different conclusion, viz that the Third World should cooperate with OECD in joint implementation of emission control measures. Shakespeare Maya showed that joint implementation can lead to marginalisation if the Third World does not develop capacity to examine the fine print "terms of trade", and thus demonstrate the need to look at political economy rather than merely economics.

The issue is not who is right, because each is bound to arrive at those conclusions based on the assumption each chooses to employ. The issue is whose assumptions are more tenable. Perhaps the IPCC WG III should ask each to criticise the assumptions of the other and to give us the results.

Institutional filters have also determined how technology is defined and cooperation through joint implementation sought. In the hierarchic mode, technology is understood only through the filter of "control"; and if the hiring of consultants can be within hierarchy-established terms of reference it is acceptable. To the egalitarians, and individualists, technology is capacity, usually self-developed. Capacity cannot be transferred: It can only be built; and SAP will not allow it to be built because it makes investment in knowledge impossible. Similarly for cooperation, hierarchies see it within practical limits but egalitarians view it with suspicion and wonder what the fine print will look like and whether it is equitable.

Equity within countries regarding climate change must be analysed within the context of other social obligations of the poor countries. When SAP is making it difficult for Third World countries to invest in social welfare (education, health, poverty alleviation), how can they allocate resources to meeting climate change convention requirements?

It may be pertinent here to this gathering to remember the history of benefit/cost analysis. It was introduced in the mid-1930s in the US water resources development to allocate scarce resources. Because of equity difficulties a Water Resources Commission was established in the US to come up with a B/C method that also took into account regional benefits as well as other social benefits. This commission worked inter-bureaucracy conflicts and finally was repealed by Ronald Reagan in the 1980s as a part of the larger Reaganite agenda of rolling back the New Deal Domestic Coalition in the US (in addition to subduing Third World Coalitions through Baker Plan and SAP).

The question is: If B/C analysis could not be applied to deal with equity issues in the most free-market of marketised societies (Ronald Reagan's California & US), what hope is there that it will work in climate change for Third World equity issues? This, to my mind is a question less for straightforward economics than for political economy and ethics.

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Rapporteur's Report

J. MANI*

Wednesday, 20 July 1994

- Population growth per se is not responsible for climate change. It was noted that population activities produce greenhouse gases and there is need to look critically at population holistically in regard to climate change.
- Environmental refugees are increasing in numbers and are estimated at 10 million. However, this figure is likely to rise to 150 million in the next few decades. They will thus become a prominent feature of the landscape.
- The most susceptible areas are islands, deltas and coastal locations.
- The question of differential impacts was analysed from various perspectives/process levels viz mega, macro, meso and micro. A special study, "The 1991 Cyclone: An Environmental and Perception Study" was presented as an illustration of some of the impacts arising from the vagaries of climate in Bangladesh. The lessons learnt from this study were twofold: that people do it by themselves and people matter; and that poverty is the killer and not the cyclone. Further, a national environmental management plan has been formulated and its implementation will involve the people. Finally, it was noted that poverty and inequity reinforce climate change.
- In capsule, the discussant noted the following:
  - equity at the national level could be enhanced through international cooperation especially in the area of research and networking;
  - the need for a Social Welfare Security System in LDCs;
  - the repeal of certain laws which inhibit a free flow of resources, goods and services;
  - removal of social conflicts which arise from inappropriate laws.
- The issues emanating from the presentation on "International Environmental Policy: Equity Considerations" were concerned with a workable Equitable Environmental Policy whose key features are:
  - level playing field;
  - technology/income transfer;
  - making low emissions a goal for LDCs;
  - specification of role of forests;
  - the issue of the right emissions approach to be articulated.

  In conclusion, it was underscored that there was an urgent need for:
  - environment dialogue;
  - development of poverty alleviation policies;
  - a mechanism for creating policy sensitivity.
- On "Equity Considerations in the Climate Debate, Technology Transfer", the presenter gave a state-of-the-art review of the North and South countries. High disparities in terms of technology advancement between the North and South were highlighted. Overall it was observed that:
  - equity is an ethical matter and does not receive the desired political goodwill;
  - cooperation between the North and South is essential for sequestration of carbon.

  On "Impacts of Human Resource and Institutional Capabilities", the following key issues were brought out:
  - human resources and institutional issues impinge on the North-South relations;
  - the North has undertaken widespread research in many areas including human resources and institutional arrangements;
  - there is an urgent need to reflect on human resource development and institutional bases in LDCs;
  - cooperation between the North and the South is a prerequisite for achieving equity.
- The importance of variability in climate change rather than climate change per se was underscored;
- It was widely suggested that knowledge intensive transfer should be resorted to rather than the conventional technology transfer. However, knowledge intensive transfer has

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the inherent problem of organisation.

- On joint implementation between the North and South, it was observed that the position of the South is not defined. However, the contentious issue of marginal abatement cost (MAC) was raised. Although it was argued that a reduction of the MAC could lead to some form of acceptable level, modern economic analysis has tended to show that MAC does not reflect well for a public good. Rather the marginal opportunity cost is the more robust measure of gains in utility rather than monetary unit. Further it was noted that trading property rights could facilitate some benefits under the Joint Implementation.
- "The Unequal Use of the Global Commons: Consumption Patterns as Causal Factors in Global Change" was a presentation which argues primarily that the solution to problems which cause and proceed from global climate change is equity. The presentation contends that the solutions will not exclusively be based on the principle of rights to equal carbon usage. A wide array of data is given in a model which draws on experiences of 189 countries from 1950–1990.
- The last presentation was on "Controlling Carbon Equity, Efficiency and Participation in Possible Future Agreements to Control Fossil Fuel Carbon Emissions". The main points of note were:
  - OECD nations cannot possibly control the future concentrations of atmospheric CO_2;
  - without the cooperation of non-OECD countries, it is mooted that concentrations of CO_2 will likely grow to more than double pre-industrial concentrations;
  - it is essential that agreements aimed at stabilising fossil fuel CO_2 emissions be made;
  - the global cost of stabilising emissions with countries/regions acting independently may be twice as high as cooperative agreements;
  - equity is entirely a new dimension and allocation of the burden to meet the cost of stabilising emissions will depend on political and ethical approaches.

In summary, it was noted that:

- perceptions are a function of society especially as relates to societal organisation;
- egalitarians carry the flagship for change rather than the hierarchical groups;
- the models highlighted by Richard A. Bradley et al. and the Global Commons Institute need to be critiqued, especially on the issue of energy in Bradley's model;
- although the cost-benefit technique is a widely recognised tool in project analysis, it has been found inappropriate in the USA, especially under the Reagan Administration;
- there is need for a pluralistic consensus on a common denominator. IPCC may wish to think along this line.

Social and Cultural Aspects of Climate Change

Chair : Lorents Lorentsen
and Alexander L. Alusa

Rapporteur: J. Kinuthia

Civil War in Sudan: The Impact of Ecological Degradation

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Environment and Conflicts Project (ENCOP) Sudan Programme
Version of December 1992

Prelude

Since the firing of the first bullet in 1983, the re-appearance of war between Northern and Southern Sudan has generally been interpreted as a typical ethno-religious conflict deriving from differences between Muslims and Christians, or Arabs and Africans.

While this categorisation had served as a description of the earlier manifestation of the conflict in the 1950s, and still has some bearing on how the war is being conducted and perceived, our opinion is that the nature of the conflict has changed. Conflicts are processes, not static events, and over the last three decades developments in the Sudan have gradually if consistently changed the nature of the conflict from being a classic ethno-religious conflict to one mainly over resources, with the economic and resource crisis in the North emerging as a driving force in the Sudanese civil war.

When the colonial powers introduced their market economy in Sudan towards the end of the last century, they simultaneously restricted its development and expansion by indigenous Sudanese in order to maintain political and economic control. After independence, however, a Sudanese "national bourgeoisie" began to evolve from a primarily mercantile social class now ostensibly freed from colonial control.

There were, nonetheless, several strong barriers to the development and progress of a middle class whose European equivalents had brought about the industrial revolution. In Sudan they lacked the major prerequisites for industrialisation—namely capital, technical and scientific knowhow and markets—and so their focus shifted from manufacturing production to the extraction of natural resources.

The collapse of attempts at industrialisation—mainly substitute industrialisation—led to exploitation of accessible natural resources in a manner so thoughtless and unscrupulous that it soon endangered the peasant and pastoralist societies in Northern Sudan. During the 1960s and 1970s Southern Sudan remained relatively unscathed, as a result of its isolation during colonial rule and the earlier civil war, and its poorly developed transport infrastructure.

Since the 1970s, the world trade system has been undergoing a structural crisis, and the efforts of the rich countries of the North to overcome this crisis had negative impact on the poorer countries of the South, clearly manifest in unfavourable terms of trade, servicing and repayment of foreign debt, structural adjustment programmes (SAPs) and a general worsening of the economic situation. This pressure has in turn been transmitted by the elite resource extractors of the South to the poorest people and their natural environment. Unfair terms of trade at international level are reflected in unfair terms of trade at the national level. Just as poor developing nations were exporting more and buying less, so the rural peasants and pastoralists were forced to produce more and buy less in the local market.

In Sudan, this meant a new expansion drive to exploit hitherto less accessible resources, mainly in Southern Sudan. A number of schemes were started, based on the exploitation of oil, water and land, and all in the name of "development", but with the profits going mainly to the Northern Sudanese elites. Although the civil war had been halted in 1972 with the Addis Ababa Accord which recognised the autonomy of the South, Southern Sudanese were denied their share of the benefits of peace. War broke out again a mere eleven years later, after the Sudanese dictator General Nimeiri had abrogated the accord he himself had signed by re-dividing the South. The situation was fuelled by Nimeiri's introduction of unjust "Islamic laws" and the siting of an oil refinery in the north. The first attacks by the newly formed Sudan People's Liberation Army (SPLA) under its leader Col. John Garang, were directed against the installations of the Jonglei Canal and oil-exploration companies.

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The renewed civil war marks the biggest onslaught so far by the mainly Northern Sudanese elite on the resource base of the South and the great cattle economies of the Nilotic groups. A small but significant number of Southerners have also been drawn into this elite, while the majority of Southerners suffered the accelerated breakdown of social structures which had already been weakened through years of neglect.

The Sudan Peoples' Liberation Movement (SPLM) grew to enjoy the support of a large section of the rural poor and was dispossessed in the North, since it addressed the fears of marginalised peoples. This marked a fundamental transformation of the original north-south division of the country, with ethnicity superseded by economic exigency. The ethnically mixed urban poor of Khartoum were able to say, "Inshallah, John Garang will liberate us". (The recent split in the SPLA—patched up again at the Abjure conference in June 1992 with the move by Garang towards the advocates of separation of the South— suggests that tribal and racial loyalties are still active factors, however, and that rhetoric may not always be matched by reality.)

The war in the South is best understood as resulting from opposing political approaches to the reality of diminishing resources. In the search for a lasting peace it is necessary to understand this new dimension to the old conflict.

The Land

In its sheer size and diversity of geography and peoples, Sudan resembles the entire African continent. More than 80% of its 25 million population live in rural areas, making up 132 tribes and sub-tribal groups in an area of 2.5 million km^2. Black Africans predominate in the high rainfall savannah of the South, with peoples of Arab origin in the desert scrublands of the North, and mixed tribes in the central low rainfall savannah.

Ironstone soils in the south give way to clay soils in the centre and desert sands in the north and west. The principal mountainous areas are the Imatong in the south, the Red Sea Hills in the north east and the volcanic Jebel Marra in the west. The general absence of mountainous barriers to the air stream means that there is a gradual change of climate with latitude. Rainfall declines from 1200 mm/pa in the southern savannah (4°N) to practically zero in the northern desert (22°N).

The River Nile runs for 2258 km from south to north, with the country's capital Khartoum sited where the White Nile is joined by the Blue Nile from Ethiopia.

The People

Recent History

The last full census (1955/56) estimated that 40% of the Sudanese population was "Arab"—in the sense of cultural rather than racial identity, since Sudanese Arabs are from a mixture of Arab, Nuba and black African stock.

The Arab tribes in central Sudan are such as the Shaygiyya and Ja'aliyyinare mainly riverain farmers, while farther away from the Nile live the Arab pastoralists and rain-dependent farmers. In the poor savannah of the north and west roam the camel breeders such as the Shukriyya and Kababish, and south of them the Baggara Arabs herd cattle.

Northerners of non-Arab descent comprise about 30% of the population: the Nubians in the far North bordering Egypt, the Beja in the Red Sea Hills, the Nuba in the Nuba mountains of southern Kordofan, the Ingessana and other peoples in southern Blue Nile Province, and the Zaghawa, Fur, Masalit and others in Darfur. In addition, there are many long-term immigrants from West Africa collectively known as "Fellata", who spread one thousand kilometres across the country from West to East. The great majority of the non-Arab Sudanese are Muslims.

The Southern Sudanese, who also amount to 30% of the population, consist of two main groups. One is the Nilotic group of primarily cattle herding Dinka, Nuer and Shilluk who inhabit the central grasslands of the South. The second group, including the Azande, Bari, Mural, Topes and many others, cultivate the wooded lands along the southern borders. Islam and Christianity have had a greater impact on these people than on their Nilotic neighbours.

The Jellaba

One important category of Arab Sudanese is the urbanised trading class known as Jellaba, who have spread all over the Sudan and into some neighbouring countries. They are the wealthiest group and have exerted considerable economic and political influence on Sudan's modern history.

The Jellaba are the descendants of Arab traders whose Islamic civilisation seemed ready for far-reaching revolutionary change a thousand years ago, (during the early phase of the Abbasid Caliphate), but imploded instead. At that time both arts and crafts were developing rapidly. There arose a new wave of poetry, with secular urban poets such as Abu Nuas and Bashar, and the refreshingly scientific and secular philosophical schools of Moutazilla and Ikhwan al-safaa, and with them a modern Arabic language devoid of flowery and ornamental jargon. All these achievements seemed to prepare the ground for a historic transformation.

But in spite of the atmosphere of impending renaissance, the revolution never took place. The feudal Arab lords entrenched themselves in their states and resisted change, the Khalifas brought in Turkish and Slavic mercenaries to uphold their disintegrating Islamic empire, and the crucial breakthrough was never made.

Instead of diversifying into production in the manner of the European middle classes, the would-be Arab bourgeoisie became entrenched in the role of "Jellaba", literally bringers of goods rather than manufacturers. For a thousand years their ancestors specialised in short and long distance trade, thus the Jellaba prefer the intricacies of commercial dealings to long-term investment in industrial enterprise, which for them remained a little known activity.

By virtue of their trading connections and geographic distribution, the Jellaba are nonetheless well organised and adaptable. Their political talent has been underestimated on many occasions, and when challenged they have retained their hold on the state either by the power of the vote or the power of the gun, acting as Dr Jekyll or Mr Hyde according to the situation.

The Crisis of Subsistence During the Middle Ages

Christian kingdoms existed peacefully side by side with their Muslim neighbours along the Nile. In the 17th century the Funj Sultanate replaced the collapsed Christian kingdoms in the north, while the Dar Fur Sultanate arose in the west. Sudan was invaded in the 19th century by an army sent by Mohamed Ali, the Turkish ruler of Egypt, who defeated the declining Funj Sultanate in 1821 and began the gradual extension of power into the south and west. The Jellaba and their private armies collaborated with the Turkish rulers in the penetration and plunder of the South.

The memory of the brutal slave trade conducted mainly by mercenaries of the northern Jellaba has lived on in the culture of the South. The experience of such aggression by Arab Muslims against black Africans gave rise to southern resistance to Islam and the embrace of Christianity, which Southerners perceived as being on their side against oppression.

To this day the majority of Northerners have chosen to ignore rather than admit the shameful history of the Jellaba, preferring to pretend that the slave trade happened in a different time and place, although a tendency to refer to Southerners as "slaves" still persists. Slave trading magnified and distorted cultural and ethnic differences and left a lasting sense of grievances and mistrust.

When the imperial powers intervened against the slave trade in the 1870s and 1880s, it caused an economic crisis which helped precipitate the Mahdist uprising which overthrew Turkish rule in 1885. However, neither Turko-Egyptian rule (1821–85) nor the Mahdist regime that followed (1886–98) effected any fundamental change in the basic structure of the economy. It remained essentially a subsistence economy, with some commercial agriculture based on the use of serfs and slaves, as well as some long-distance trade ties with Egypt and to the East.

In 1898 a coalition of British and Egyptian forces overthrew the Mahdists and reconquered Sudan, setting up a colonial condominium state which sought to establish "the rudiments of a modern capitalist economy whilst at the same time opposing its full blown indigenous development, since this would create a political threat to itself... At the political level, during the 1920s, a Native administration was created from the rubble of the Mahdist period".[1] Independence in 1956 created the political conditions for the Jellaba to break away from the constraints of direct colonialism. By the 1960s their focus had shifted from the pump-irrigated cotton schemes of the 1950s (such as the White Nile schemes) to large scale mechanised farming of sorghum and sesame in rainland areas. These spread from eastern Sudan southwards into Blue Nile Province and then west into southern Kordofan and Darfur.

Today the area under licensed mechanised cultivation, at more than 4 million ha (over nine million feddans), exceeds that under traditional rainfed agriculture (3. 8m ha/ 9m feddans). The former "supports" some 8000 largely absentee farmer-landlords, while the latter is the livelihood of 2–3 million "peasant" farmers.

The tractorisation and intensification of agriculture dealt a severe blow to traditional peasant farming, with the gross social and environmental change it inflicted on peasant and pastoralist societies.

Low-technology agro-pastoralism began to collapse across the central clay plains of northern Sudan, and a new and burgeoning category of impoverished people emerged who were dependent on selling their labour to survive. Many migrated to the towns, considerably swelling the numbers of the urban poor.

Unlike the migration of the European peasantry during the Industrial Revolution, this move was not towards centres of higher economic production, but to areas of greater food availability—mainly through food aid. A historical pattern is being echoed in tragic fashion. Another consequence of the rapid impoverishment of the

[1]M. Duffield, "Sudan at the Crossroads", IDS Discussion paper 275, Sussex University 1990 (p. 8).

northern Sudanese traditional peasants and pastoralists is the abandonment of relatively benign methods of exploitation of nature and their replacement with aggressive methods which assume that natural resources are limitless.

In creating a class of local resource-extractors, the inclusion of Sudan in the global market economy has directly impoverished both the environment and the rural people who depend on it for survival.

The Resources

Agriculture is the major economic activity of the Sudanese people, of whom about 80% are engaged in crop production and animal husbandry. The principal food crops are sorghum and millet, while the cash crops are cotton, groundnuts, sesame and gum arabic. The main animal wealth comes from cattle, sheep, goats and camels.

Sudan has some 36 million ha (85m feddans) of arable land, of which only one third is cultivated, owing to constraints of water availability or the heavy nature of the soil. A further 100m ha (240m feddans) are usable as grazing land and 17.6m ha (42m feddans) are natural forest. Of the 13.5m ha (32.5m fed.) gross cultivated area, some 1.9m ha (4.5m fed.) are under irrigation, 7.5 m ha (18m fed) under rainfed mechanised farming and 4m ha (10 m fed.) under traditional cultivation.

The current livestock population is estimated at 27.7 million Animal Units (AU), much greater than the optimum stocking rate of 22.1 AU [1 AU = 1 cow + 1 calf or their equivalent]. The range resources are also reduced by expansion of cultivation, by deforestation and by grass fires, which burn up to 30% of the total forage production.[2]

Forests are being decimated in the North by the expansion of mechanised farming and increasing demand for fuelwood. At current rates of consumption versus regeneration and afforestation, all forest areas in Northern Sudan will be denuded by the year 2003.[3]

All rivers in Sudan are part of the Nile waters system. In addition to the White Nile and Blue Nile, the Bahr al-Arab, Dinder, Rahad and Atbara rivers flow into the main Nile. With the exception of the Bahr al-Arab, all the other perennial tributaries of those rivers originate either from outside the Sudan or from Southern Sudan: This has an important bearing on the civil war. Rainfall, the only other water source, is characterised by wide variability of distribution within the same isohyet in any one season, and this is reflected in both run-off and seepage variability. Crop production and the welfare of livestock fluctuate greatly in accordance with the rainfall patterns.[4]

Human and animal life depend on a delicate balance of the soil, water and flora that support it, and disruption of any one of these vital elements creates havoc. Factors such as climate change, land exhaustion through over-use or misuse, population growth or displacement, disadvantageous changes in land tenure, warfare or export of resources cause lasting damage to the people, the animals and the environment.

All the following disastrous factors have descended on the country within the life-span of one generation:

- Micro- and macro climate change (the practically continuous Sahel drought since 1967)
- Diminishing and erratic rainfall and accelerating desertification (the floods and torrential rains of 1988)
- Near doubling of population in less than a quarter of a century (15.4m in 1970 to 25.4m in 1990)
- Displacement—both internal and external—of some six million people
- Doubling of livestock numbers within 20 years
- Deforestation on a massive scale
- Renewed civil war in the South, which is now encroaching on the west and east
- Aggressive expansion of legal and illegal rainfed mechanised farming, from 0.42m ha (1m feddans) in 1967 to 7.5m ha (18m fed.) in 1989.

To prepare the ground for far-reaching changes in the land tenure laws and traditional practices, the Sudanese state introduced a new land act in 1970. The 1970 Unregistered Land Act declared that all land, occupied or unoccupied, belonged to the state and entitlement could no longer be acquired by long use. Only about 1% of crop and grazing land is privately owned. The subsequent distribution of "state land" to absentee landlords, encouraged the reorientation of agricultural production for export purposes. This move was sanctioned by the international "market forces" who favour cash crops for export rather than food for the internal market. (The shift of focus of agricultural production from the internal market to the external market.)

It is a deeply disturbing indicator of the devastation of the social fabric and the natural environment that Sudan's relatively small population is increasingly unable to sustain a livelihood in a huge and resource-rich country. The discovery of oil in commercial quantities at the beginning of the 1980s raised hopes of salvation of the country's economic crisis. But

[2] A. Mougrabi, Hydrobiology Unit, University of Khartoum (unpublished paper).
[3] M. Suliman, *Greenhouse Effect and its Impact on Africa*, IFAA 1990.
[4] DANIDA, *Sudan Environmental Profile*, Ministry of Foreign Affairs, Denmark 1989.

the oil was found mainly in the South, and as with the prospect of saving water with the Jonglei Canal, success depended on control of the area.

The Civil War in the South

The Events

The Anglo-Egyptian Condominium government took 25 years to subdue Sudan. This was especially difficult in the south where until the 1920s, the government consisted largely of punitive military expeditions and periods of exceptional violence.

To pacify and govern the North, the new rulers promoted the political and economic influence of Sayyid Ali al-Mirghani, head of the Khatmiyya sect and Sayyid Abd al-Rahman al-Mahdi, head of the Ansar sect. Sayyid Abd al-Rahman reconstituted and to some extent secularised the Ansar organisation, which became the Umma political party, while Sayyid al-Mirghani patronised the emergent nationalist movement, led by Ismail al-Azhari, and transformed the Khatmiyya followers into the Democratic Unionist Party, DUP.

While the British concentrated on economic, political and infrastructural developments in the North, such as the Gezira scheme, the railways and the introduction of modern civil administration, it allowed the West and South to stagnate under the "native administration" of the chiefs and sheikhs.[5]

This policy towards the South amounted to total separation of South and North—tribal structures were maintained—little or no effort was made to promote social or economic development—and education—with English rather than Arabic as the lingua franca—was elementary and minimal. The result was not only isolation of the South from the North, but also from the rest of the world.

In the 1930s and 1940s nationalist political activities in the North were developing at a rapid pace. Catalysed by internal and external developments associated with the Second World War, the political pressure led to independence in 1956.

The colonial powers only began to loosen their grip on Southern Policy in 1948, when the Juba Conference was allowed to take place, and southern chiefs agreed with northern nationalists to pursue a united Sudan.

"The crash programme of integration that then occurred was too little, too late. In 1953 the 800 administrative posts vacated by the British were 'Sudanised'. The northern politicians allocated a mere four posts to the Southerners; an insult but also an indication of how education in the South had lagged behind. In the south, 'Sudanisation' was tantamount to 'Northernisation'. As independence approached, the Southerners saw their British administrators being replaced by Northerners. In 1955 the southern garrison at Torit mutinied on hearing that they were to be transferred to the North. Their rebellion formed the nucleus of the Anyanya separatist movement, which was to fight Sudan's first civil war for seventeen years".[5]

The 1972 Addis Ababa Accord

Since independence the Sudan has alternated between civilian and military rule in a fruitless search for economic development and the resolution of the Southern problem.

In July 1971, when Nimeiri was returned to power after a short-lived coup supported by the Communist Party, he severed all connections with the "socialist" countries and rushed headlong to embrace the West and the prospects held out by its "free market" philosophy. For his grand new plans to succeed, peace was crucial. In 1972, following negotiations with Joseph Lagu—who only two years previously had brought the Anyanya movement under his sole command—Nimeiri and Lagu signed the Addis Ababa Accord that brought an end to 17 years of civil war. The basis of the agreement was regional autonomy for the South, but it left several key issues only half answered.

The years between 1972 and 1983 were years of uneasy peace. Many Equatorians were unhappy about what they felt was the hegemony of the Dinka in the Regional Government, which became the major source of wealth and social prestige in the South. The balance of power between Equatorians and Nilotes was altered in 1979 with the fall of Idi Amin in Uganda and the return to Sudan of many well-qualified Equatorian professionals and administrators.

Most Southerners were disdainful of the way Nimeiri interpreted the Addis Ababa Accord to redraw the boundaries of the South to include the Bentiu region, where oil had been discovered, into the North. This feeling was compounded when central government ignored the concerns of local people when it gave the go-ahead for the construction of the Jonglei canal through the swamps of the Sudd.

Southern politicians were also divided amongst themselves. Equatorians against Dinka and Nuer, Anyanya "haves" against Anyanya "have-nots". Nimeiri tried to exploit these divisions to his own advantage and began manipulating the course of events by appointing and dismissing senior southern politicians. These machinations culminated in the "redivision" of the South in

[5]Africa Watch, *Denying the Honour of Living—Sudan, A Human Rights Disaster*, London 1990.

1983. Three regions were created out of the one autonomous region, and the single regional government was abolished. While Equatorians rejoiced, the unseated Dinka and Nuer felt humiliated and deceived. The spectre of a new civil war began to haunt the South, but this time the Nilotic tribes were bound to be the major actors. In the same year that Nimeiri redivided the South, a number of mutinies took place, notably the one at the garrison at Bor, which then became the nucleus of the Sudan People's Liberation Army (SPLA) of Col. Dr John Garang.

The SPLM/SPLA

The SPLA, unlike the Anyanya movement, announced that it was not fighting for an independent South: Its declared aim was a unified secular and democratic Sudan. The SPLA saw itself as an integral part of the struggle of all the marginalised groups in Sudan, including the Nuba and Fur. John Garang has repeatedly called for a national constitutional conference to agree on a secular and democratic constitution for the whole country. It has always been questionable, however, whether the SPLA would be able to maintain this position in the face of huge practical and psychological obstacles, not least that most of its rank and file were motivated to fight by ethnic and religious differences. During the early years of the movement, Ethiopian government support was crucial to the SPLA, and since Ethiopia had problems with its own secessionists it would have been unwilling to assist in action likely to lead to a re-drawing of international frontiers. (Since the fall of the Dergue in May 1991, of course, the Eritreans have succeeded in just such a revision.)

Internal dissent in the SPLA reached crisis point in August 1991, when a break-away group—the "Nasir faction"—called for the overthrow of Garang and for a separate South, abandoning all ambitions for a unified secular state. Although they failed to unseat Garang, they revived the principle that "self-determination" took priority over unity, and voiced a common southern attitude that the difference between the Islamic Front regime and the opposition Umma and Democratic Unionist Party was minimal: That Northerners could not be trusted. It is now debatable how long Garang and his supporters —the "Torit faction"—can keep to their original slogans.

The end of the Cold War has meant diminishing strategic importance in the global sense for Sudan, but other considerations have come to the fore and are gaining momentum. The Islamic fundamentalist movement has expansionist ambitions, and the people of neighbouring Egypt have an ever-growing demand for water. In the shifting sands of the new politics of the region, all participants are forced to reconsider their course of action, and the SPLA is no exception.

The Koka Dam Agreement, March 1986

Following the overthrow of Nimeiri in 1985, the "National Alliance" of radical political forces that led the popular uprising met the SPLA/SPLM at Koka Dam in Ethiopia and reached an agreement on a basic formula for peace, including the convening of a constitutional conference. The Koka Dam Agreement was endorsed by the Umma Party and rejected by the DUP and the National Islamic Front (NIF).

The Umma Party leader and new Prime Minister Sadiq al-Mahdi soon abandoned Koka Dam, however, having successfully revived the old Mahdist alliance of Jellaba and western Baggara and obtained huge arms supplies from Libya and Iraq. He began to pursue the war with renewed vigour, arming the Murahaleen militias, whose loyalty to him "would be greater than their accountability to the law and the state".[5]

By the end of 1988 the DUP was sufficiently concerned about Sadiq's intentions that it negotiated the "November Accords" with the SPLM/SPLA, agreeing in principle to freeze the Islamic Sharia laws pending a constitutional conference, to implement a cease-fire and cancel the state of emergency imposed by Sadiq in 1987. The popularity of this agreement was demonstrated when DUP leader Mohamed Osman al-Mirghani was given a hero's welcome at Khartoum airport on his return.

Faced with massive popular endorsement of the November Accords—and implicit condemnation of his own stance—Sadiq al Mahdi turned to the NIF for support, setting up a new coalition government which excluded the DUP. But the army had become convinced of the futility of the war, and in February 1989, dismayed by the lack of political resolve, issued an ultimatum to Sadiq: Unless there was progress towards peace, and the militia were disbanded within one week, the army would step in.

Eventually Sadiq capitulated; the NIF left the government and the DUP returned. Negotiations were started with the SPLA; a cease-fire was achieved fairly quickly, and the UN famine relief programme Operation Lifeline was resumed.

The Constituent Assembly agreed to freeze the Islamic laws, and a date—18 September 1989—was set for convening the constitutional conference. Sadiq was due to meet Garang in Addis Ababa on July 4.

The meeting never took place. On June 30, with perfect timing, a military coup staged by the NIF aborted the peace process and with the fervour of "jihad" unleashed a reign of terror in the North as well as the South. The new regime escalated the war in the south to new levels of brutality with the backing of radical Islamic and Arab countries. Iran, especially, became a source of enormous military and economic support.

The NIF has been singleminded in its resolve to solve the "southern problem" once and for all with a programme of Islamisation and Arabisation. The DUP and Umma Party both regarded the South as a natural extension of their economic base, their strategic resource reserve, and they would rather see the continuing devastation of war than accede to southern demands for self-determination.

The Causes

Few wars are ever fought in the name of their real causes: Instead they are fought under old banners and old slogans, based on memories of past conflict. Because these memories fade so slowly, they obscure from the valiant warriors the possibility that they might be fighting for reasons no longer relevant or valid and even, on occasion, against their own interests.

This is partly the case in Sudan's current war. Although the major cause of the conflict is now the struggle over resources, most fighters on both sides remain convinced that the war is all about ethnicity, cultural identity and religion. In the following, I will try to explain this transformation in the nature of the conflict, by discussing the major elements of the process.

The Cultural-Ethnic Divide

Sudan is a vast country that for long periods most Sudanese tribes were able to live in their homelands in relative isolation from each other, free to develop their own cultural values and norms. Only when forced to move from their traditional habitats by reason of ecological degradation or political coercion did they have to confront alien cultures and peoples. These points of contact became strong ethnic identities, whether Arab or African, were also the areas of friction and potential for low and high intensity conflict.

When Southerners are in conflict with the North, their identity with the region and self-image as black Africans come first, while at the local level tribe attachment is predominant. Apparent unity is more complex than it seems, and long and bitter conflicts have often divided neighbouring peoples. In the North, although there are evident regional and tribal loyalties, they often give way to class-based distinctions.

The Jellaba, the secular-educated and the army officers constitute what Dr Alex de Waal calls the Sudanised groups.[6] The three groups share a cluster of common features: A language (Arabic), a religion (Islam) and a common cultural code, a hybrid of northern riverain cultural values.

Historically, the Jellaba traders were partly responsible for the slave trade which transformed the cultural borders between the Northern "Arab" tribes and the Southern "African" tribes. From borders of cultural exchange and mutual enrichment they became barricades from behind which to shoot at one another.

The Southern Policy

Following violent military expeditions to gain control of the South, the colonial government imposed a different system of administration, known as the "Southern Policy". While in the North control of the economy and administration was mainly in the hands of the State and secular leaders, in the South the colonial government created self-contained tribal societies, headed by traditional chiefs. The government tried to eradicate all Muslim influence, encouraged missionary activities and used English as the lingua franca.

No effort was made at economic development. Education was elementary; no secondary education was available. "At its height, the Southern Policy led to the attempted creation of a 'cordon sanitaire'; a depopulated no-man's land between north and south... There were also suggestions of federating the south with Uganda".[5]

In the decades of isolation from the North and the rest of the world, the memory of the slave raids was kept alive,with virtually no personal contact to dilute its bitterness. Consequently, when the administration of the South was "Sudanised" by the introduction of Northerners prior to the early years of independence, and the sons of the Jellaba slave traders confronted the Southerners as their new rulers, the ethnic friction soon caught fire. Hundreds of Northern traders, professionals, teachers and others were killed in the massacres which in 1955 swept through the South in response to what was perceived as northern colonialism.

This was a shocking reminder to the North that it would take more than earnest declarations to transcend entrenched mistrust and enable peaceful communication to take place between alien cultural identities.

The Resource-Extractors Versus Rural Sudan

The arid and semi-arid zones that make up most of the North are over-populated, even though the population density is only about ten inhabitants per square kilometre. This is because the populations are concentrated around sources of

[6]A. de Waal, *War in Sudan—An Analysis of Conflict*, Peace in Sudan Group 1990.

drinking water and good soil. Over the centuries people in the Sahel have developed many coping mechanisms to counteract occasional drought. But since 1967 rainfall has consistently been less than the previous long-term average, and the survival techniques have come under unbearable pressure from such persistent drought.

There has been a precipitation deficit of 40–50% compared with the preceding 15 years.[7]

During the 1970s and early 1980s it was widely believed that the Sahel drought was man-made; a result of the destruction of vegetation through over-grazing and deforestation for timber and fuelwood. Since the mid-1980s expert opinion has swung towards the view that changes in ocean temperature caused by global warming might be the main culprit.[8] However, both the regionally and globally induced changes are in the last instant the result of human interventions, the ongoing human-ecology transformations.

In addition to drought, unsustainable methods of land use such as over-grazing and intensive mechanised rain-fed farming are destroying the Sahelian ecosystem in which 70% of the Sudanese people live.

It is the contention of this paper that the subsistence economy of this huge Sahelian zone has collapsed irreversibly as a result of human activity and climate change. The slower natural process of wear and tear has been accelerated enormously by the unprecedented exploitation of resources carried out by the Jellaba, prompted by their assimilation into the world market in the restricted role of extractors of primary wealth. In addition, the loan conditionalities of the IMF and the World Bank considerably boosted this restructuring of resource utilisation away from local needs and the local market towards the demands of the international market. In this process, the decline in the international terms of trade brought about by the collapse of primary commodity prices had a knock-on effect on the local market, where terms of trade have also worsened. To maintain their living standards the peasants and pastoralists had to produce more from their shrinking resource base. Failure to do so meant joining the millions of newly asset-less poor.

The Fragility of the Dry-Lands[9]

The southern fringes of Sudan's semi-desert zone used to have sufficient rainfall to support the cultivation of drought-resistant millet and a few other crops, but even this subsistence production has become virtually impossible because of three spells of drought in the last two decades.

Savannah covers about 25% of Sudan, known as the central rainlands, where agro-pastoralism is the principal method of land use. Rainfall averages 800 mm per annum across this belt of acacia and tall grass, where the more fertile soil supports sorghum, millet, sesame, groundnuts and cotton.

This belt extends to the rich savannah in the South which gives way to the tropical forest and swamp in Equatoria, large areas of which are not suitable for raising livestock because of the presence of the tsetse fly.

The fragility of the arid and semi-arid lands is evident. "Awareness of seasonality and careful utilisation of resources are supplemented with herd diversity and selective use of certain environmental niches in specific seasons of the year... The sequence of environmental security building is based on utilising the richer southern zones in the event of long periods of drought".[9]

This movement of people and herds from one ecological zone to an area already occupied by different ethnic groups is already a recipe for tension, requiring delicacy of negotiation. Conditional agreements used to be reached when the need for sharing land was occasional, but now that the need is permanent the strains are greater. Furthermore, when the buffer zone between the semi-desert and the savannah is blocked by large-scale mechanised farms, then the entire way of life of the agro-pastoralists collapses.

Mechanised Farming in the Central Rainlands

The total area under legal or licensed large-scale irrigated and rainfed mechanised schemes increased from less than half a million hectares (one million feddans) in 1968 to about five million hectares (9 million feddans) by 1986. An equal area is farmed illegally by the same methods.[2] These large-scale private schemes took over great stretches of traditional farm land, water points, grazing lands and herding routes, displacing millions of small producers. Large areas of forest were cleared (including about 95% of the forest in eastern Sudan) to make way for the giant agricultural schemes, and with the trees went vital local sources of revenue from fuel wood and gum arabic.

It is noteworthy that the Mechanised Farming Corporation, (MFC), was established in 1968, upon request from the World Bank to secure its first loan for the so-called supervised sector and to facilitate credit to private farmers.

[7]F. Ibrahim, *Ecological Imbalance in the Republic of Sudan*, Druckhaus Bayreuth Verlagsgesellschaft GmbH, Bayreuth 1984.

[8]F. Pearce, "A Sea Change in the Sahel", *New Scientist* 2 February 1991.

[9]M. A. Mohamed Salih, "Political Coercion and the Limits of State Intervention". In *Ecology and Politics* (Edited by Hijort af Ornäs A. and Mohamed Salih M. A.), Scandinavian Institute of African Studies, Uppsala, 1989.

The MFC supervised the expansion of mechanised agriculture into southern Kordofan, White Nile and Upper Nile Provinces. By 1975 the World Bank provided half of the total loans for the agricultural sector, specifically for private rainfed mechanised farming.

The ecological and social stress caused by large-scale mechanised agriculture is well documented, and can be held responsible for three types of conflict:

1. Conflicts between traditional farmers and owners of the big schemes, as documented by Ahmed:

   > "Cultivators are forced to sell their labour cheaply, pastoral nomads are driven out of the best areas of their traditional pasture... and agro-pastoralists are forced to abandon one of two activities and change over to agricultural labour for low wages and a lower standard of living".[10]

2. Conflict among local people in the vicinity of the schemes, because of scarcity of cultivable land, obstruction of animal herding routes or in the search for fresh grazing land.

3. Conflict between the state, as major backer of the scheme owners, and the small farmers and pastoralists. This is the most serious of all as the state has often opposed the spontaneous resettlement of such people when stricken by drought.

The very structure and location of the large-scale mechanised farms is a source of recurrent and continuous confrontation:

> "Their mere location in the intermediate land between the semi-arid zone and the rich savannah is a potential source of conflict... The whole intermediate lands have now been transformed into an arena of conflict not only between the traditional producers but also between the modern and the traditional sub-sectors of the agricultural system".[9]

It is interesting to note that during the period of rapid expansion of mechanised farming from 1970 to 1985, more than 20 major regional tribal conferences were organised to solve land disputes between the various ethnic groups in the central rainlands.

Enter the World Bank and the IMF

During the 1950s and 1960s agricultural production was directed mainly to the internal market and the satisfaction of basic local needs. For this reason Sudanese people were able to withstand the severe drought of 1972–75 without the emergence of widespread famine. Since the mid-1970s and the involvement of the IMF and World Bank in Sudan, however, the situation has changed. A significant shift took place within the Jellaba with the opening to the West that started in 1972 and the move from internal markets to export. By the mid-1970s Sudan was being hailed as the potential breadbasket of the Arab World, and plans were laid to expand mechanised agriculture westwards using freely available petro-dollar loans. Objection to these policies became evident with the revolt of the indigenous agricultural parties—two coup attempts were made, one by Hassan Hussein in 1975 and the other by Mohamed Nurin 1976.

In spite of the rapid increase in the area of land under cultivation and the increased export capacity, the overall effect of the new export-oriented policies was negative. The value of primary commodities in the international market declined steadily from the early 1970s onwards while at the same time oil prices soared to record heights. Foreign debt was growing, as were repayments and servicing dues. The economic crisis came to a head in 1978, when the IMF intervened and negotiated the first of several adjustment programmes. From then until 1984 the IMF concluded five agreements with the Sudan. The IMF structural adjustment programmes (SAPs) were directed towards curbing the government's budget deficit and encouraging the export sector, mainly through selective promotion of export crops and devaluation of the Sudanese currency. By greatly encouraging the expansion of mechanised farming, reducing the land available to traditional farmers and pastoralists, devaluing their monetary assets and reducing subsidies for basic needs and social services, the whole edifice of agro-pastoralism—the livelihood of 14 million Sudanese began to collapse. Because agriculture was no longer geared towards the domestic market, the living conditions and spending ability of the labouring classes became a secondary issue.

Between 1978 and 1984, a further 4.5 million people joined the army of the asset-less, and at the same time:

> "not only had the crisis within the subsistence economy deepened, producing a growing poverty of a new type unsupported by traditional systems of redistribution and reciprocity, but the economy had been redirected towards external markets, becoming increasingly vulnerable in the process. The result was the well-publicised famine of 1984–85".[1]

The Sorghum "Success Story"

By 1980/81 sorghum had become the Sudan's second largest export. Increase in sorghum exports was due mainly to import subsidies by Saudi Arabia, which paid $220/mt for Sudanese

[10] A. M. Ahmed, "National Ambivalence and External Hegemony". In *Agrarian Change in the Central Rainlands* (Edited by Mohamed Salih M. A.).

grain, compared to only $170/mt for sorghum from Thailand.

The IMF pressure on Sudan to export continued unabated, even during the famine years of 1982/85. During this period the Sudan exported 621,000 metric tons of sorghum, prompting praise from leading IMF economists for an apparent success story "an interesting example of the role of devaluation in encouraging non-traditional exports".[11]

Cotton Versus Food

Prior to the implementation of SAPs, wheat self-sufficiency averaged 48%. After the SAP implementation had begun (1978–87) the figure deteriorated to 26%. This was a direct consequence of IMF bias against wheat production because it clashed with profitable export crops such as cotton.

The area under wheat was halved to make way for increased cotton cultivation: The World Bank gave generous support to the rehabilitation of the Gezira and other irrigated cotton growing schemes. In view of the depressed market for cotton, Sudan lost on both counts—foreign currency earnings and food security—because of increased dependence on wheat imports, whether commercial or concessional.[12]

Political Coercion and the Privatisation of the State

The internal conflicts which have mushroomed in the Sudan from the mid-1970s onwards have reflected the growing resistance of millions of dispossessed against the new economic regime based on export of resources. To implement these policies with their harsh effects on an embittered population, the commercial and financial interests of a significant part of the Jellaba required a new type of state, which is completely within the grasp of their elite group and endowed with strong powers of coercion.

Coercive acts against traditional cultivators and pastoralists were swift and brutal. When victims of famine and drought moved into the wetter zone in search of survival alternatives, they were often intercepted by the army. The only way left open for survival was to move to towns and relief centres; to eke out a degraded existence dependent on begging, charity and petty labour or theft and prostitution.

Even in the towns these people were treated as third class citizens. The police were mobilised in arbitrary round-ups known as "kasha", which sought to repatriate the migrants to their homelands, despite the fact that the land could no longer sustain them. These uprooted and homeless people are collectively known to the authorities as Shamasa, literally "those who have no roof but the sun".

State aggression escalated in line with growing poverty and resistance. In 1983 Nimeiri introduced his harsh version of the Islamic Sharia laws, and the penalty of amputation was enforced on 200 people in eighteen months. All were displaced Shamasa.

Resistance continued,however,with the Shamasa providing the spark for the 1985 popular uprising which, in informal alliance with the impoverished middle class of public employees, teachers and professionals, overthrew Nimeiri's military regime. In 1986 parliamentary democracy was reinstated, but it did not take long for people to realise that very little had actually changed or was likely to change, since the same interest groups continued to implement the same policies as before.

Eventually the more ruthless business and finance segment of the ruling elite became impatient with the obstacles created by the new democratic atmosphere, the democratic checks and balances in the state apparatus and the judiciary, and the prospect of concessions to the South in the search for peace. They wanted the system dismantled and irreversibly destroyed, and so staged a putsch against an already weakened civilian government and intensified the war.

The Move Southwards

Mechanised farming reached southern Kordofan and the Rahad reserve area by the end of the 1970s. By 1989, some 60% of the Rahad reserve was under illegal mechanised farming, and it is astonishing that the government has provided these illegal and unlicensed schemes with agricultural extension services and even fuel quotas.

The horizontal expansion of mechanised farming exhausts the soil very rapidly. Yields of sorghum, millet and groundnuts of the degraded land fell by as much as 80%, and some 17m hectares have been lost to soil erosion. In some areas the land is depleted within 3–4 years by this large-scale version of shifting cultivation, which rolls like a fire-ball across the land, deforesting and destroying the soil before moving on. Its appetite for new land is rapacious and continuous, and the only natural direction for it to go is southwards.

With the discovery of oil at Bentiu, the Jellaba became aware of a new form of wealth in the

[11] Nashashibi and Clawson, "The IMF Supply Side Approach to Devaluation: A Response", *Oxford Bulletin of Economics and Statistics*, February 1986.

[12] M. N. Hussein, *Food Security and Adjustment Programmes: The Conflict in Environment and Women* (Edited by Suliman M.), IFAA 1991.

South to add to those of land and water. As far as the Jonglei canal was concerned, its construction during this period paralleled the agricultural expansion drive even though it had been contemplated for several decades.

By the end of the 1970s the South, which had been left to its own devices for so long, was moved into the sphere of interest of the Jellaba and their state.

The Lure of Oil, Water and Land

Oil

In April 1981 Chevron announced the discovery of commercial deposits of oil in the Unity field in its southwestern concession. Recoverable reserves from Unity and the adjacent Heglig field were officially estimated at about 236 million barrels. Confirmed oil reserves for the whole of Sudan are estimated at 2000m barrels —enough to earn the country some $10,000m or cover its projected energy needs for ten years.

Original plans to process the oil locally were deferred in September 1982; instead, with Chevron's encouragement, the Nimeiri government opted for the construction of a refinery and export terminal south of Port Sudan, linked to the oil fields by a 1400 km pipeline. This sudden reversal alerted people in the South to the probable intentions of Nimeiri and his backers among the Jellaba. One of the first acts of the SPLA was to attack Chevron's oil field operations, forcing the company to suspend work in February 1984.

Since then, and in spite of pressure from Nimeiri and all subsequent governments, oil operations in the southwest have practically halted.

Water

Since the beginning of the century the idea of constructing a canal to drain the Sudd marshes of the White Nile at Jonglei has been debated by developmentalists and environmentalists. Motivated by the desire for more water downstream and the prospect of uncovering a vast expanse of fertile land, the Jonglei canal is one of the most intensively researched water projects in the world. What has always been conspicuous by its absence, however, is any serious assessment of how the local people—some 1,700,000 Dinka, Shilluk and Nuer, Murle, Bari and Anuak directly and indirectly affected by the project actually felt about it.[13]

Actual construction of the Canal began in 1978; a joint Sudanese-Egyptian project working with the French CCI company. Aimed at conserving some 4000 m^3 of water lost annually through evaporation the operation was forcibly suspended in 1984, having completed 250 km of the proposed 360 km, following a series of attacks on the construction site by the SPLA.

Egypt desperately wants the additional water represented by its half share in Jonglei, to help grow food for its burgeoning population. Before the expansion of mechanised farming, the Sudan was not under the same pressure to obtain water. Since the mid-1970s, however, water has become the limiting factor for agricultural expansion in many parts of northern Sudan, since new irrigation projects need more water.

The 450,000 Dinka, Shilluk and Nuer who were directly affected feared the drastic changes the Canal would bring to their way of life. They could not accept the prospect of life without the migration to the toich during the dry season, when they would find fish and improve the milk yield of their cows. They also feared the prospect of alien people being settled in their midst, and the possibility of conflict. Rumours that Egyptian farmers would be sent to the canal area sparked student riots in Juba in November 1974. There was justifiable mistrust of the project from Southerners who saw the North and Egypt benefiting while their own lives were irreversibly changed, and not for the better. By drying out the swamps and taking away the "grass curtain", the canal would open up the entire Sudd area for mechanised farming, the domain of the Jellaba, and also allow the north to move military equipment and troops into the South with greater ease. Thus the project's giant earth-excavating machine, the biggest in the world, was one of the SPLA's earliest targets, much to the chagrin of the governments of Sudan and Egypt.

The Land

The fertile savannah plains of acacia trees and tall grass is where the "breadbasket" was envisioned. More predictable rains make these plains suitable for sorghum, millet, maize, sesame, groundnuts and cotton. The huge expansion of large-scale mechanised farming which constantly devours new land, spread into southern Kordofan and the northern parts of Upper Nile province. The owners of the mechanised farms, having exhausted vast traits of the north, pushed inexorably southwards into the area inhabited by the Nilotic tribes, the major cattle economies of the South. Having seen how the Nuba were squeezed off their land in southern Kordofan, the local people were hostile to this incursion, and their response was the same.

[13]George Tombe Lako, "The Jonglei Canal Scheme as a Socio-Economic Factor in the Civil War in the Sudan". In *African River Basins and Drylands Crises* (Edited by Darkoh) OSSER 1992.

Since the mid 80s the Nuba began to join the SPLA in large numbers, attacking and burning the large mechanised schemes. There was a similar reaction from the people of the Ingessana in the southern Blue Nile province, who have also become sworn enemies of the mechanised farmers. And in northern Upper Nile and Bahr al-Ghazal, the main stream of the SPLA attacked government troops and forced mechanised farms to close down.

Once again the plans of the Jellaba were frustrated. The call for strong government as the only solution to all Sudan's problems began to spread, and with the National Islamic Front (NIF) coup its advocates got exactly what they were looking for. When the new cultural attache at the Sudan Embassy in London addressed the Uppsala Forum in August 1991, he said:

> "The trade unions, sectarian lords, big merchants, tribal leaders, *have all grown very powerful in the absence of effective state power...*The winner in the long struggle for supremacy is as often as not determined by single-minded ruthlessness and efficacy rather than by any other qualities". [italics mine].

And:

> "... the primary obstacle to the establishment of a proper state in the Sudan had been the refusal of the South to cooperate... their resistance has weakened the state and deprived it of its legitimacy..."[14]

The NIF's military regime has intensified its brutal treatment of Southerners, including those fleeing the war, and has used inter-tribal rivalry and some corrupt southern intellectuals to spread conflict among them. It has also destroyed the relative autonomy of the state apparatus that constituted a potential threat or obstacle to the implementation of its aims.

The Resistable Rise of Islamic Fundamentalism

One implication of the austerity measures and currency devaluations of the IMF's SAPs was the impoverishment of the middle classes and a marked polarisation among the Jellaba themselves. In the new economic atmosphere only the Jellaba, with strong connections to finance capital and to the state power, could prosper.

> "In response to the declining profitability of more conventional activities, commodity speculation, hoarding and the use of state office for personal gain have grown in importance... The leading edge of this new economic regime has been the Islamic banking system, which first appeared in Sudan with the opening of the Faisal Islamic Bank (FIB) in 1978. This development found political expression in the fundamentalist National Islamic Front, NIF".[1]

On the international level the success of the Islamic revolution in Iran raised the hopes and aspirations of all fundamentalist movements in the Islamic World. They were also assured of a high degree of direct material support from a relatively wealthy state, an element that has been missing for quite a long time.

The leadership of the Islamic fundamentalist movement in the Sudan is made up of urban, male, northern intellectuals with strong connections to the business and finance sectors. They have a strong anti-rural bias. Because of the shortened time in which to show a return on investment, they have adopted adventurous and aggressive forms of accumulation. Aggressive accumulation often demands an aggressive state and people with a single-minded determination and ruthlessness. The ideology behind the movement must appear pure, straight and simple, backed up by swift deterrent punishment for transgression (fascism, fundamentalism, etc.). The breathtaking speed of the NIF's transformation from the "softly-softly" Muslim Brotherhood to a quasimilitary organisation can only be explained by the move from liberal accumulation methods by the segment of the Jellaba, represented by the NIF, to the aggressive, ultra-capitalist short-termism of the last decade or so.

South-South Conflict

When the government's armed forces take prisoners of war from the SPLA, they are usually executed, and reports by Amnesty International and Africa Watch back up a picture of thousands of extrajudicial executions in the Nuba Mountains and the South. Atrocities against the civilian population were committed not only by the armed forces but also by a number of militias organised and armed by the government. The Murahaleen militias were drawn from the "Arab" tribes of the west—the Rezeigat, Misiriya, Humur, Zurug and Rufaa tribes—who had traditionally engaged in skirmishes with neighbouring Dinka over grazing lands. These encounters had hitherto never escalated into war, and peace was usually restored fairly quickly by means of inter-tribal conferences and longstanding protocols for settlement of disputes.

Smaller Southern tribes distrustful of Dinka hegemony in the SPLA were also formed into pro-government militias, their opposition often stemming from harsh treatment at the hands of the SPLA. The Mundari at Terekeka responded in this way, as did the Toposa, Acholi Latuka, Madi and Azande in other parts of Equatoria. Remnants of the Anyanya 2 and the Murle militia operate in Upper Nile, and the Fertit make up the main pro-government "Popular Defence Force" in Bahr al-Ghazal. The Khartoum regime plays

[14]A. Al-Affendi, "The State, Politics and the Southern Question". In *The Current Situation in the Horn of Africa* (Edited by Mohamed Salih M. A.) Scandinavia Institute of African Studies, Uppsala 1991.

off one against the other. Although the North-South conflict is gradually losing its predominantly ethnic aspect, in the smaller scale South-South conflict this aspect is still alive and killing. The split in the SPLA in September 1991 probably had more significant negative impact than the entire militia operations, and although it represents division over policy and leadership, the driving force behind the rupture also had a strong measure of ethnic tension. When Commander Dr Riek Machar, a Nuer, and Dr Lam Akol, a Shilluk, announced the overthrow of SPLA leader John Garang, a Dinka, they failed to dislodge him but set in motion a tragic chain of tribal killings. Such events feed off long-standing rivalries.

In my opinion the SPLA split, and the dissidents' adoption of calls for a separate South, represent widespread fatigue with the ideological aspect of the movement. The declared aim of a united, secular, democratic state had come to seem impossibly utopian, and the example of neighbouring Eritrea and its secession (following the fall of the SPLA's socialist mentors in Ethiopia) seemed to open up new possibilities. Since the breakup of the Soviet Union and the rise of nationalism, the temptation—always present—to say "Why fight and die for a North that will never treat us as equals?" must have been very strong. The northern opposition, the National Democratic Alliance, has not been involved in the fighting, yet the problem of Islamic fundamentalism is mainly that of the North, not the South. Many Southerners question the wisdom of fighting on behalf of the opposition parties of the North. Colonel Garang has pragmatically moved to accommodate the possibility of separation with a joint call for "self-determination", keeping all of his options open.

Conclusions and Prospects for Peace

Conclusions... From Ethnic to Ecological Conflict?

Sudan is such a large country that over long periods most Sudanese tribes were able to live in relative isolation from each other. This isolation encouraged the development of strong ethnic identities very suspicious of all aliens. An unhappy diversion from this tradition occurred during the slave trade period, when the Northern Jellaba raided the South and enslaved thousands of its people. However, the implementation of the so called Southern Policy the South and the North returned to mutual isolation. With the advent of independence northern Sudanese replaced the colonial administrators and brought back all the ethnic suspicion and mistrust, never forgotten nor forgiven. The ethnic conflict erupted violently in 1955 and continued unabated until the signing of the Addis Ababa Peace Accord in 1972. In the same year all attempts at independence from international capital were abandoned. The temporarily successful coup of so called free officers backed by the Communist Party in July 1971 gave them a shock, but with international backing the coup was rebuffed and the same forces hung on to the levers of state power. The price for this reprieve was the dropping of all pretence to independence from the international market and the lifting of all the barriers to foreign capital and "mutual cooperation". Within two decades of this surrender, some tremendous upheavals had taken place—man-made and otherwise.

- About six million people mainly in northern Sudan have become assetless and homeless poor. Some 4–5 million people are displaced inside the country, and some 2–3 million have left the country either as migrants or as refugees.
- Practically all remaining forested areas in northern Sudan, an area the size of western Europe, have been denuded—17 million hectares of rainfed arable land.
- Half the total of usable land have lost topsoil and turned irreversibly to dust. Crop yields fell to 30% of their previous levels in some areas of rainfed agriculture.
- Rainfall has been less than half the average, and its occurrence has been more erratic.
- Industrial production, mainly substitute industrialisation, averaged only 15% of capacity. Foreign debt went up from $ 298 in 1972 to $14 billion in 1992 .Capital flight also reached a staggering $14 billion. The Sudanese pound lost 99.7% of its value, falling from three US dollars to one US cent.
- Population growth rate increased from 3.0 to 3.5%, resulting in a 60% increase in numbers. Social services deteriorated to an absurdly low level. Illiteracy, previously declining, began to rise.

The unprecedented exploitation of the central clay region of the Sudan through extensive tractorisation coupled with persistent drought exhausted large areas in the North and forced the unscrupulous landlords to expand in the virgin lands in the South, the Nuba mountains and the Ingessena region. By the end of the 70s they started a number of schemes based on the oil, water and land resources in the South. The response of the South was the formation of the SPLM/SPLA. It is very significant, that the first attacks by the SPLA were directed against the installations of the Jonglei Canal and the oil exploration companies. This new resource aspect changed the character of the war. The indiscriminate killings of Northerners, as was the case during the first civil war, became no longer significant. On the contrary, some Northerners and many people from the Nuba and Ingessena joined the ranks of the SPLM/SPLA, which maintains that it is defending the whole of rural Sudan against the onslaught of the Jellaba. Many of the fighters from both sides of the divide may still conceive the war as an ethno-religious conflict. The truth of the matter is that these elements are no longer as prominent as before and that the competition over resources triggered by ecological degradation in the North may already be the most important factor in the second civil war in the Sudan.

Here we have an outstanding example of an ethnic-cultural conflict being gradually but firmly transformed through persistent ecological degradation into a resource conflict.

The large-scale mechanised farming which is the main culprit of the ecological degradation is best understood as *large-scale shifting agriculture* exploiting the soil to the limit before moving to fresh land to repeat the process. It destroys the basis of survival for the people as well as the flora and fauna. The mechanised touch turns everything to dust.

In my opinion, the Sudan offers a prime example of how Third World ruling elite, driven to specialise in resource utilisation, have degraded the resource base to such an extent, that its expansion becomes a necessity for them, justifying aggression against their own people and/or their neighbours.

The Prospects for Peace

Bearing the abovementioned in consideration means that the prospects for lasting peace will depend on understanding the changed nature of the conflict. It is our contention that to avert future conflicts it has been imperative to drastically change the present mode of land-use by halting the senseless tractorisation of vulnerable lands, abandon the monopoly of the state over land-ownership and reorientate agricultural production to the internal market and the satisfaction of people's food needs.

Lasting peace will therefore depend on:

1. Land reform, to return the land to its original owners, rolling back mechanised farming and nullifying concessions of large tracts of land to absentee landlords.
2. Assisting the peasants and pastoralists to rehabilitate their natural habitat.
3. Direct agricultural production to meet food self-sufficiency needs, by gradual, selective de-linking from international trade as it is currently practised.
4. Exploring all the links, the direct and the intricate, between implementing sustainable development policies and the maintenance of lasting peace.
5. Achieving far-reaching democratisation in all walks of life as well as respect in law and praxis of the rights of all minorities. Empower the people and they will green the land.

At the beginning I mentioned Sudan's resemblance to the entire African continent. Unfortunately that resemblance extends to the narrow specialisation in production demanded by the international market, namely that of primary producer and therefore depletion (par excellence) of resources.

The rural people, the Shamasa and the impoverished middle classes have been struggling for two decades against the effects of this myopic asset-stripping. It would be a tragedy for Sudan and its people if the outcome of the civil war means the continuation of the resource war of which it is but one manifestation.

Impact des Variations Climatiques sur l'Evolution des Conditions de vie dans les Communautes Pastorales Touareg et Fulbe de la Region Lacustre de l'Issa-Ber au Mali

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Introduction

La région lacustre de l'Issa-Ber était réputée pour son élevage de bovins de qualité; il était pratiqué, principalement, par les Maures et les Touareg au nord et les Fulbe, au sud. Ils exploitaient de riches pâturages de bourgou *(Echinochloa stagnina)* renouvelés chaque année par la pluviométrie et la crue de l'Issa-Ber.

A partir des années 1969–1970, la configuration de la région a immédiatement changé. La période de sécheresse, qui persiste depuis ces vingt dernières années, s'est aggravée entre 1984–85, pire que celui de 1972–73. La conséquence a été la destruction rapide des ressources naturelles, la restriction de l'espace vital des éleveurs et l'avènement d'une immense détresse humaine et animale (Reichelt, 1989). Il n'est pas dans notre propos d'interpréter le phénomène du changement climatique; ce texte se propose, surtout, d'examiner les incidences et/ou les effets[1] des récentes variations climatiques sur l'évolution des conditions de vie économiques, sociales et culturelles chez les communautés pastorales locales. Il s'agit, en d'autres termes, ici, d'examiner les relations d'interdépendance entre l'évolution de l'environnement et les réactions et stratégies d'adaptation des éleveurs aux nouveaux modes de vie.

Le texte s'articule autour de trois chapitres essentiels:

- Le premier chapitre est un rappel des conditions écologiques et environnementales de l'élevage;
- Le deuxième chapitre décrit le mode d'utilisation traditionnel des ressources naturelles;
- Le troisième chapitre examine les transformations économiques, sociales et culturelles et les nouvelles réactions de réadaptation à la sécheresse persistante. Ce dernier chapitre est suivi d'une conclusion.

Les Conditions Écologiques et Environnementales Locales de l'Élevage

La Région Étudiée

La région lacustre, telle que nous l'entendons et telle qu'elle est présentée sur les cartes IGN, est délimitée par les parallèles 15°30' et 17° nord et les meridiens 3° et 5° ouest. Elle concerne les deux rives du fleuve Niger, sur une transversale sud ouest nord est, entre le lac Débo et Tombouctou. Elle est située en aval du Delta intérieur, dont elle constitue l'extrémité septentrionale. C'est une région qui tranche nettement avec le Delta par l'alternance très régulière de dunes et de couloirs inondables, donnant au réseau hydrographique une allure dense et complexe. Celui-ci est formé par une multitude de lacs, de mares et de marigots situés à la périphérie, alimentés directement ou

[1]Le changement climatique est la modification du climat dû aux activités humaines, notamment par l'accroissement dans l'atmosphère de certains gaz comme le dioxyde de carbone provenant de la brûlure des combustibles fossiles et du déboisement, — Les chlorofluorocarbones provenant des enterprises industrielles.

Notons que l'accroissement de ces gaz à effet de serre, se traduira principalement par un réchauffement global entraînant une augmentation de la température moyenne à la surface du globe de 1,5 à 4,5°C au cours des 100 années à venir.

Certains indices laissant à penser que le rechauffement aurait déjà commencé car les températures moyennes à la surface du globe semblement avoir augmenté de 0,3 à 0,6°C pendant les 100 dernières années. De nombreux climatologues y voient la manifestation d'un changement réel.

Les conséquences probables du changement climatique dans nos zones peuvent se résumer en:

— une diminution des chutes de pluie, de l'humidité; une forte évaporation etc., provoquant ainsi de fortes chaleurs qui montront en péril les cultures, le bétail et les hommes.

indirectement par l'Issa-Ber et ses défluents, à l'époque des crues, entre juillet et février:

- sur la rive droite ou Gourma (songhay), les lacs Korarou, Aougoundou, Niangaye, Do, Garou, Haribongo, Kabongo, etc.;
- sur la rive gauche ou Haoussa (songhay), les lacs Tanda, Kabara, Soumpi, Takaji, Horo, Télé, Takara, Faguibine, Gouber, Kamango, et les deux Daouna, Béri et Keyna.

C'est l'interconnexion de ces lacs, mares et marigots qui constitue le complexe de plan d'eau et d'artère fluviale, d'où le nom de région lacustre de l'*Issa-Ber* (Fig. 1).

Les Conditions Climatiques

Située entre le 17e parallèle au nord et le 15°30' au sud, la région étudiée est soumise à toutes les nuances de transition du climat sahélien, depuis les influences sahariennes au nord jusqu'aux marges soudaniennes au sud (100 à 400 mm/an). Le mécanisme de cette climatologie a été suffisamment étudié par des chercheurs compétents (Auberville, 1949; Idiart, 1959; Gallais, 1967; Courel, 1984). Il n'est donc pas nécessaire pour nous de rentrer dans le détail.

Pour simplifier, disons que de novembre à avril, sous l'influence de l'anticyclone du Sahara, les alizés du nord-est soufflent continuellement. La température baisse progressivement pour atteindre le minimum en janvier. Elle s'accroît ensuite et le maximum est atteint en avril. La nébulosité disparaît, l'hygrométrie baisse et les précipitations sont pratiquement nulles. Le sol se dessèche en profondeur; les réserves en eau sont épuisées, la végétation herbacée est desséchée, certains arbres et arbustes perdent leurs feuilles. En mars, le FIT se trouve vers le 18ème parallèle, en position équatoriale. Puis, il se dirige lentement vers le nord pour atteindre le 18ème parallèle en août. La saison des pluies ou hivernage s'installe sur l'ensemble de la région, jusqu'en fin septembre. Pendant cette période, la végétation reprend activement et les travaux agricoles, profitant de l'humidité, sont accélérés. Après quoi, le FIT redescend vers le sud, marquant la fin de la saison des pluies, et le début de la saison sèche.

Notons que l'essentiel des pluies dans cette région tombe sous forme d'orages et d'averses

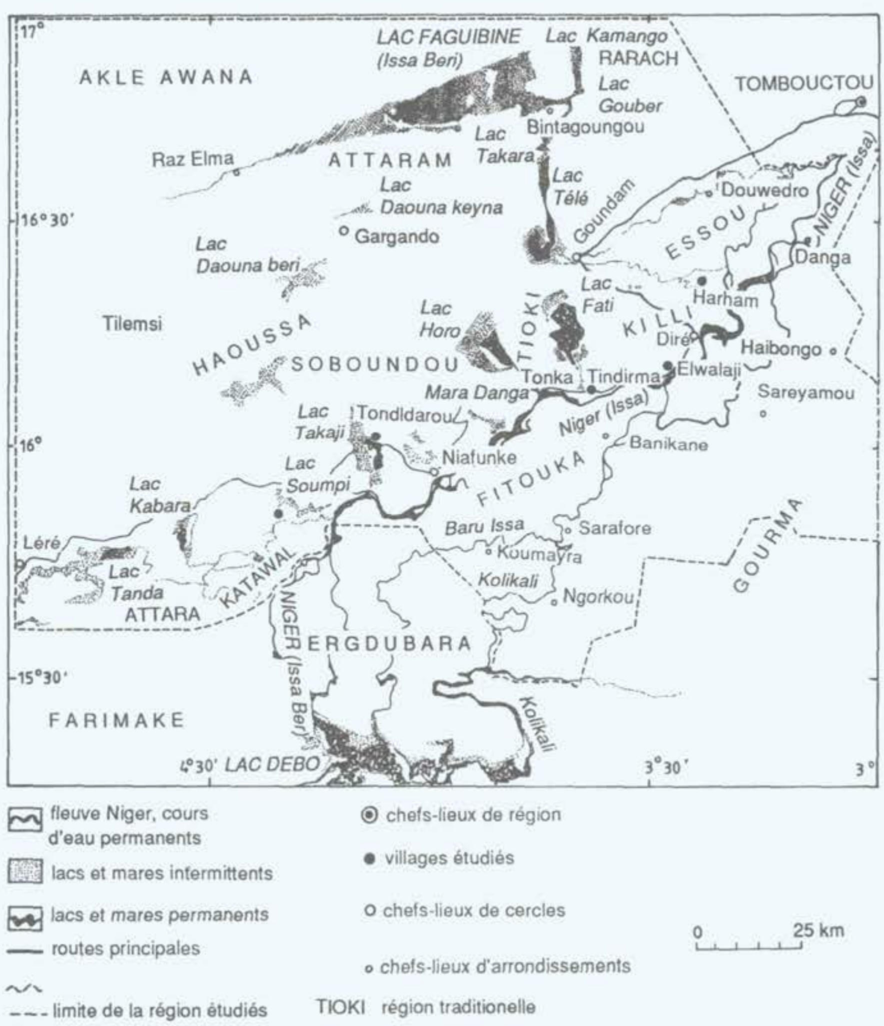

Fig. 1. La région d'étude.

violentes de 10 à 30 minutes, souvent, très localisés; fréquemment, des secteurs relativement proches peuvent ne pas en bénéficier.

Conclusion. Le climat de la région lacustre de l'Issa-Ber peut être défini comme un climat sahélien typique (100 à 400 mm/an) mais de nuance sub-aride. Localement, il est fonction de plusieurs facteurs dont les plus importants sont: les saisons, les vents, les crues du Niger, les températures et la pluviométrie. Cette dernière se caractérise par une grande variabilité interannuelle (Fig. 2), saisonnière et journalière. Elle demeure le facteur limitant majeur et ses conséquences sont d'autant plus désastreuses, que le déficit pluviométrique s'étend sur plusieurs années consécutives. Climat de transition, cette situation fait que tout est en équilibre instable, et les périodes sèches ou humides sont difficiles à prévoir. Ce qui pose de nombreux problèmes d'évolution des milieux naturels et de mise en valeur agricole, pastorale et piscicole.

Conditions Hydrologiques

A sa sortie du lac Débo, le Niger prend le nom de l'Issa-Ber (le grand fleuve). Relié à de nombreux marigots, chénaux et canaux naturels, l'Issa-Ber alimente de près ou de loin de vastes plaines et un semis de lacs et de mares. On peut distinguer dans ce bassin plusieurs zones naturelles: d'ouest en est, le Farimaké, l'Attara, le Soboundou, le Katawal, le Tioki et le Killi. Toutes ces contrées sont parsemées de plaines marécageuses, de lacs et de mares. Dans ce troncon les variations de la pente (260–270 m) donnent au fleuve la forme d'un sinusoïde presque parfait.

Après son embranchement, en aval de Diré, la zone d'épandage s'elargit, l'Issa-Ber alimente alors une succession de petits deltas adventifs, formant le Kessou, triangle de terres délimité par les marigots de *Katoua,* à l'est, de *Tassakan* au nord et de *Kondi* au sud. Ces deux derniers confluent à quelques kilomètres de Goundam pour former le marigot de Goundam qui, par le lac Télé, alimente le système lacustre du Faguibine. Ce secteur comporte, en outre, de nombreuses îles. Puis le réseau hydrographique se simplifie pour reprendre son cours normal en formant à nouveau une boucle parsemée d'îlots jusqu'a Korioumé, à hauteur de Tombouctou, où finit le Niger lacustre.

En conclusion, l'Issa-Ber et ses affluents, ainsi que ses nombreux défluents et émissaires, constituent, malgré l'irrégularité des crues et des pluies, de véritables artères de vie pour les populations rurales. On leur doit l'alimentation des dépressions (mares et lacs) et des nappes souterraines. Notons cependant que ces eaux de surface connaissent actuellement un abaissement général, lié à une diminution considérable des débits de crue et d'étiage (Fig. 3 et 4).

Variations Climatique et Utilisation Traditionelle des Ressources Naturelles

L'élevage est l'une des plus vieilles activités traditionnelles de la région. C'est un élevage extensif, pratiqué selon les principes du nomadisme, de la transhumance et de la sédentarité. Son organisation remonte aux XV et XVIème siècles, avec les empereurs songhay, mais elle a été renforcée au XIXème siècle par la

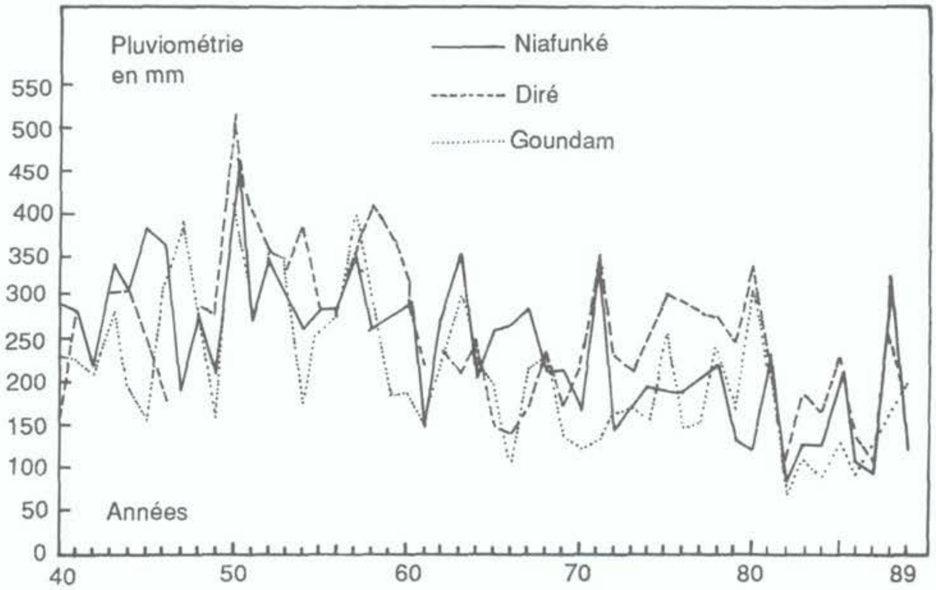

Fig. 2. **Comparaison de la variation annuelle de la pluviométrie à Niafunké, Goundam, Diré, de 1940 à 1989.** Outre la grande similitude entre ces trois stations, on peut aussi remarquer que la station de Niafunké, plus méridionale, est plus pluvieuse que celles de Diré et de Goundam.

Dina de Sékou Amadou. La domestication des animaux et le contrôle de leur reproduction sont, depuis des siècles, le quasi monopole des Fulbe et des Touareg dans tout le Soudan occidental. Au fil du temps, cette spécialisation a pris la forme d'une identité socioprofessionnelle, et même ethnique. Le mobile principal des différents modes d'élevages est de garantir aux éleveurs une meilleure flexibilité dans l'exploitation des ressources hydrauliques et fourragères sujettes à une très forte variabilité spatio-temporelle. Ainsi, grâce à un système d'alternance et de rotation saisonnière des animaux, le surpâturage est le plus souvent évité et les points d'eau judicieusement utilisés dans des conditions écologiques particulièrement difficiles depuis la sécheresse des années 70–80.

Les Éleveurs

Trois catégories de populations se livrent, traditionnellement, à l'élevage: les grands nomades (Maure et Touareg), les semi-nomades (Fulbe), et les sédentairres (Songhay, Bambara, Soninké). Pour les deux premières, le pastoralisme fut une activité économique et culturelle essentielle produisant plus de 80% des revenus.

Les Grands Nomades

Les fractions ou tribus majoritaires sont: les Maures (Tormoz, Ideylouba, Ousra, Kounta, Berabich, etc.) et les Touareg (Tenguereguif, et Kel Antessar) nomadisant entre les étendues sahélo-sahariennes et la vallée du fleuve, via la zone des lacs. Celle-ci leur sert de région de relais en saison sèche. Ils ont très peu de villages fixes, se déplaçant avec toute leur famille et tirent, exclusivement, leurs revenus de l'élevage. Toutefois, quelques tribus s'adonnent à l'agriculture par l'intermédiaire de leurs esclaves bella (Iklan). Ils sont éleveurs de bovins, mais surtout spécialisés dans celui des ovins, caprins, et camelins. Ils ont trop souffert des récentes sécheresses (1973–74, 1984–85) et ont perdu tout leur bétail. La tendance du mode de vie est à la sédentarisation forcée.

Les Fulbe

Les Fulbe sont les plus grands éleveurs de la région pour lesquels l'élevage est presque, dit-on, une religion. Selon Lalanne (in G. Doutressoule, 1950, p. 24): *"L'amour du Pullo pour les boeufs est tel qu'il connaît ses animaux un par un par leur nom (tiré de la couleur de leur robe), qu'il sait très exactement leur filiation, les services rendus par telle femelle féconde, les caprices de tel taureau furieux..."*. Contrairement aux precédents, les Fulbe sont semi-nomades, une partie de la famille vit au village toute l'année, l'autre consituée de bergers se deplace avec les troupeaux transhumants. De manière générale, les sédentaires d'un groupe pratiquent l'agriculture en s'appuyant sur la collaboration des serviteurs (Rimaïbé). Leur aire de parcours est comprise entre la zone des lacs, des mares et le fleuve. Les lacs Horo et Fati jouent le rôle de plaque tournante pour les différents itinéraires de la transhumance. Aujourd'hui, avec la décimation du bétail, beaucoup ont retrouvé leur salut dans l'agriculture et le petit commerce et/ou

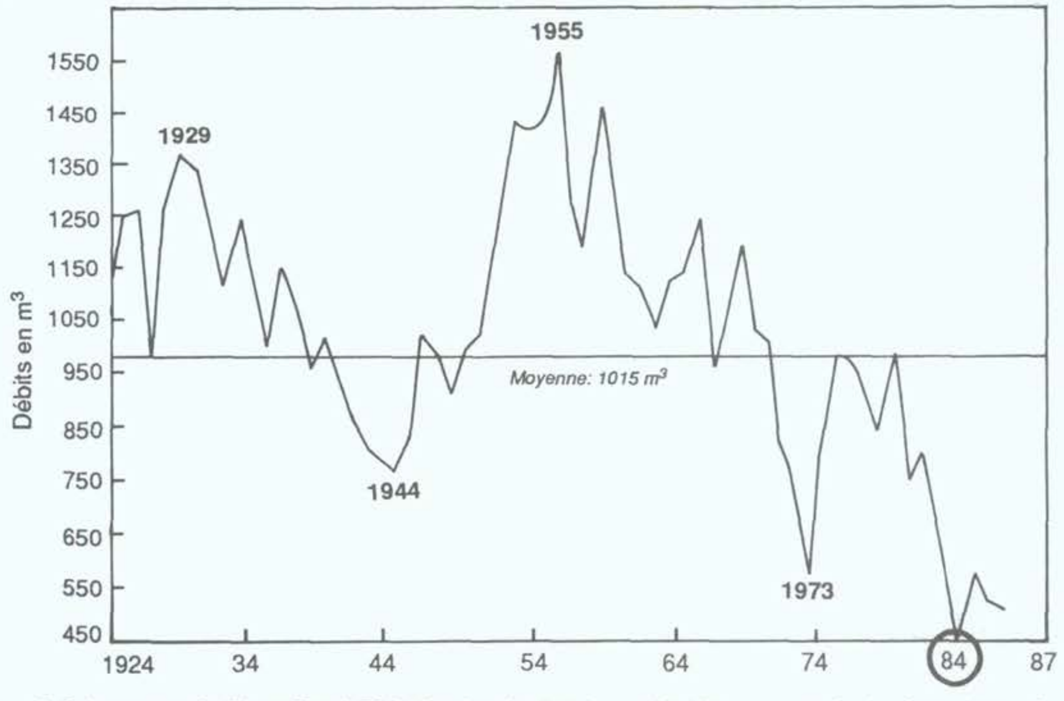

Fig. 3. **Débit moyen de l'Issa-Ber à Diré de 1924 à 1987.** L'année 1984 marque le plus bas niveau de crue jamais enregistré au cours des ces soixante dernières années. Elle a eu les effets les plus catastrophiques de mémoire d'homme. Les pics correspondent aux remplissages du lac Faguibine.

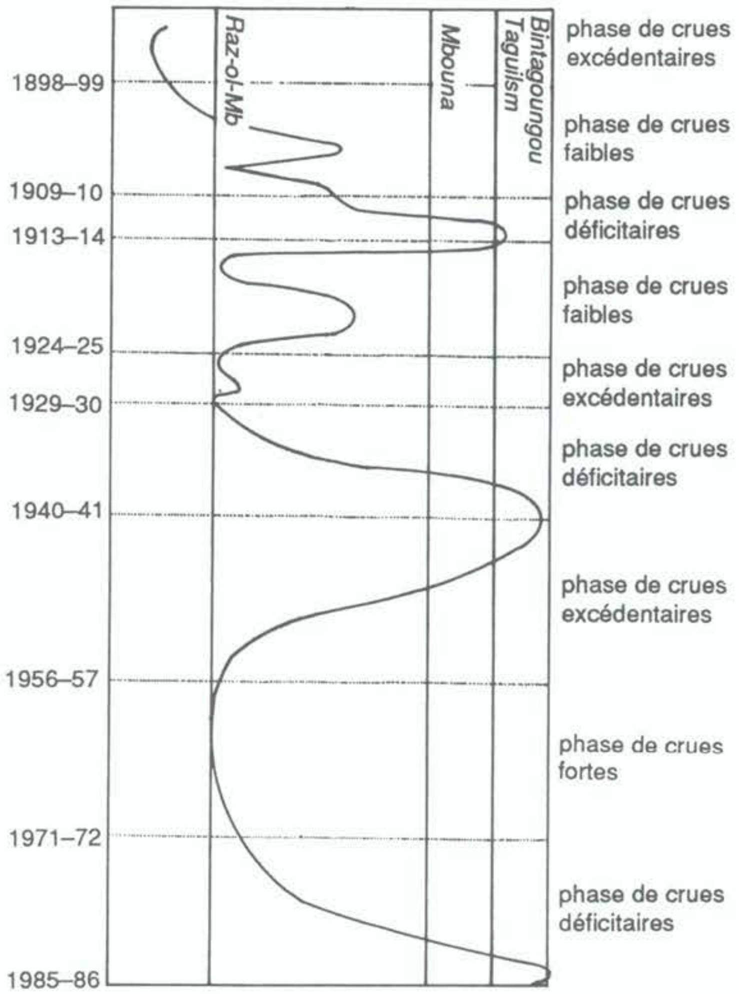

Fig. 4. **Variation de l'extension de la cuvette lacustre du Faguibine de 1984 à 1986 (dans A.- M. Catella, 1988).** Cette figure illustre parfaitement les manifestations locales dans les fluctuation des crues de l'Issa-Ber.

sont devenus des bergers pour les grands propriétaires autour des villes.

Les Sedéntaires

Ils disposent, eux aussi, de troupeaux relativement importants. En effet, depuis toujours, ils ont investi les exédents de leurs activités agricoles dans l'achat de bétail. Car, pour l'agriculteur, le bétail est source de placement en prévision des mauvaises années. La garde des bovins, ovins et caprins est confiée à un berger Pullo ou bella. Pendant la période des crues et des cultures, le gros de ce bétail vit en transhumance avec celui des éleveurs Fulbe et Touareg. Certains sont devenus depuis la sécheresse de grands propriétaires d'animaux.

Connaissances Locales et Utilisation Rationnelle des Ressources

L'étude des données physiques a permis de définir le caractère semi-aride de la région, caractère qui peut être résumé par la variabilité extrême de la pluviométrie, un abaissement constant de l'eau dans les lacs, mares, puits et puisards.

En somme, il a été démontré que le caractère désertique de la région progresse. Les systèmes d'élevage pratiqués sont fortement liés à ces conditions physiques. Ainsi, trois facteurs s'imposent: la recherche de l'eau, des pâturages et des terres salées, suivant les saisons de l'année.

La Recherche de l'Eau

Le facteur de vie essentiel est l'eau. En effet, ce sont les abreuvoirs qui déterminent, avant tout autre facteur, les mouvements pendulaires des troupeaux formant la base même du nomadisme et de la transhumance. Dans l'année, les animaux utilisent alternativement quatre types de points d'eau: les mares d'hivernage, les puits, les lacs et le fleuve.

Le Potentiel Fourrager

Les pâturages représentent le deuxième élément fondamental conditionnant la vie des troupeaux. L'état des pâturages, rappelons-le, est fonction des saisons, de la nature des sols et des zones écologiques. Ces facteurs permettent ainsi de distinguer trois types de pâturages: les pâturages de dunes et de plateaux, les pâturages de décrue du fleuve Niger (ou bourgoutières) et les pâturages de résidus de culture après les récoltes. Cependant, sans chercher à les caractériser tous, les pâturages de décrue demeurent les plus importants et les plus recherchés par les animaux.

L'importance des bourgoutières est telle qu'il y a une concurrence farouche entre les différentes tribus Fulbe et Touareg, malgré l'existence d'un code pastoral délimitant pour les unes et les autres des zones réservées de bourgoutières. Les Fulbe prétendent que les grandres bourgoutières comme celles du Débo et de Macina sont leur propriété. Ainsi, ils essaient d'imposer aux touaregs des droits de redevances.

Ces derniers, en se référant à l'histoire de l'occupation du sol, font valoir leur qualité d'anciens suzerains. Tous les ans, des heurts meurtriers sont enregistrés par l'administration. On peut relever dans les archives coloniales et même actuelles, la liste de ces conflits. Par exemple, de 1927 à 1971, plusieurs séries de bagares sont évoquées, opposant les Fulbe aux Touareg au sujet de l'utilisation des bourgoutières par les animaux de ces derniers.

La tension est la même entre ces pasteurs et les agriculteurs, car les bourgoutières défrichées sont d'excellentes rizières. C'est pourquoi chaque atteinte à leur existence provoque des querelles incessantes comme actuellement.

Les Terres Salées

C'est la troisième composante qui, elle aussi, est déterminante dans le tracé des itinéraires de la transhumance. Ce sont des terres imprégnées de sel de soude, à l'état de chlorure et de sulfate, avec une certaine quantité de magnésie.

Au milieu de l'hivernage, les animaux, une fois rassasiés en herbe, éprouvent de par leur comportement alimentaire l'urgence de gagner les terres salées. Celles-ci présentent plusieurs vertus: combler les déficiences minérales de l'alimentation et purger les animaux en opérant un déparasitage intestinal; engraissement par regain d'appétit, amélioration de la lactation et incitation des géniteurs à l'accouplement. Le passage aux terres salées est organisé par tribu et par fraction de tribu. Les plus connues, dans la région, sont celles de la plaine de Rimi, à Gargando et de l'Aslagh à l'Ouest du Tilemsi. Ces endroits sont particulièrement célèbres pour la plante à saveur salée, *Cornulaca monacantha (had en M)*. La première cure salée à, en principe, lieu dans la deuxième quinzaine d'août, durant l'itinéraire aller; une seconde est observée, en septembre-octobre, sur le chemin du retour, suivie d'une cure d'eau limpide au fleuve ou des lacs. On pratique rarement une troisième cure salée.

Voici donc en gros esquissés les facteurs qui règlent les parcours des troupeaux et les différents modes d'occupation de l'espace en fonction des saisons.

Les Oscillations Saisonnières

Elles apparaissent comme un facteur essentiel d'accessibilité des troupeaux aux ressources fourragères et hydrauliques. Il est possible de les systèmatiser en trois grandes périodes:

- La période juillet–septembre: Correspond à la saison des pluies, le paysage est parsemé de pâturages et de points d'eau; les troupeaux se trouvent au nord pour utiliser les ressources disponibles;
- La période octobre–février représente celle de la saison froide; la rareté de l'eau oblige les troupeaux à redescendre dans la zone centrale (Tilemsi, Daouna, Farache, etc.) autour des puits et à la périphérie des lacs et mares permanents; la progression des déplacements se fait lentement vers la vallée du fleuve;
- La période mars–juin: Coïncide avec la saison chaude, période de soudure où la seule alternative de survie pour les troupeaux reste la descente dans les bourgoutières.

Tel est schématiquement décrit le rythme saisonnier. Tout le long de l'année les mouvements des troupeaux s'effectuent à intervalles réguliers et dans les directions toujours identiques ce qui en fait un phénomène cyclique (Doutressoulle, Ibid. 1950).

Les conditions d'ensemble étant ainsi posées, il semble maintenant aisé d'aborder les différents systèmes d'élevage et les techniques de production.

Les Systèmes d' Élevage et les Techniques de Production

Ils sont en relation directe avec les facteurs abordés précédemment, mais aussi les traditions culturelles propres aux différents groupes sociaux s'adonnant à l'élevage. Au total, trois systèmes d'élevage sont pratiqués dans la région:

- l'élevage nomade,
- l'élevage Pullo (ou semi-nomade),
- l'élevage sédentaire.

Nous indiquerons, pour chacun de ces systèmes, les caractères spécifiques en ce qui concerne l'utilisation de l'environnement.

Système d'Élevage Nomade

P. Galloy (1963, p. 11) définit comme nomade "la population de race blanche ayant un genre de vie nomade saharien ainsi que la population de race noire relevant socialement et économiquement de la précédente". Il s'agit donc, en général, de populations sans villages fixes, en perpétuel déplacement en fonction des saisons et des besoins des troupeaux.

Ce mode d'élevage a été jadis l'apanage des grands nomades maures et touaregs du nord de Niafunké et de Goundam. Il consistait en de grands déplacements de tout le troupeau (*Tassaram,* Tamacheq), en compagnie de la famille *(Ehene* T*)* sur des vas-tes étendues à des dates et dans des directions souvent imprévisibles (SEDES, 1972), sous la conduite des bergers bellas. Les animaux, composés de bovins, ovins, caprins et camelins, fréquentent rarement les rives du fleuve, sauf en cas de nécessité. En effet, il s'agit d'animaux rustiques bien adaptés aux longs parcours sahélo-sahariens, mais très sensibles au parasitisme endémique des zones humides. Un proverbe targui ne dit-il pas: *"le chameau est mal où pousse le mil?"* Mais sans entrer dans le détail, disons que ce système d'élevage est en déclin depuis plusieurs années. Cela est dû, à la fois,a la précarité des points d'eau et des pâturages, mais aussi à la régression numérique des troupeaux, à la suite de la sécheresse. Aujourd'hui, les nomades ont adopté la transhumance ensemble de mouvements pendulaires de rythmes saisonniers nord-sud-nord et de caractère cyclique, des troupeaux à l'intérieur des pâturages coutumiers (WIP, Ibid., 1980).

Ainsi, pendant l'hivernage, de juillet à septembre, les troupeaux maures et touaregs montent dans l'Aklé, au nord de Raz-el-Ma et du Faguibine, pour exploiter les pâturages dunaires et les mares temporaires; en saison sèche, à partir d'octobre, ils redescendent vers la zone des puits et de la périphérie des grands lacs (Faguibine, Télé, Fati, Horo et Takaji), jusqu'à épuisement des pâturages environnants; en décembre–février, les mouvements s'amplifient en bordure des lacs Tanda et Kabara, en attendant la date officielle de rentrée dans les bourgoutières; en saison chaude (en mars), une fois le départ donné, les troupeaux se répartissent en deux axes différents: un premier flux se dirige vers les pâturages naturels du Méma et de Nampala des bourgoutières du lac Débo ou du Macina. En juin–juillet, dès les premières pluies, le même mouvement reprend en sens inverse.

Les troupeaux des nomades sont difficiles à chiffrer avec exactitude, car de nombreux pasteurs ont préféré quitter la région pour le sud du pays, plus riche en eau et pâturage. Toutefois, en saison chaude, plusieurs milliers de têtes de bétail se trouvent rassemblés dans la zone des lacs et le long du fleuve. Selon certaines estimations que nous avons eues à Tonka, le cheptel nomade represente environ 20 à 30 % du total régional.

Système d'Élevage Pullo

A la différence des grands nomades, les Fulbe, en raison de leur semi-nomadisme et/ou semi sedentarisme, ont presque toujours opté pour le système de la transhumance. Celui ci tire son organisation du Code pastoral de la Dina sous Sékou Amadou. La structure du troupeau comporte:

- *le garti* (ou troupeau transhumant),
- *le benti* (ou troupeau de vaches laitières et de veaux se déplaçant non loin des villages d'origine pendant la crue),
- *le dounti* (ou petit troupeau de vaches laitières gardé au village par les femmes et la périphérie des villages. L'extension des cultures limite considérablement l'ampleur de leurs déplacements.

Le garti constitue donc le gros de la structure du troupeau transhumant. En hivernage, les troupeaux se trouvent dans le Tilemsi et les Daouna; en saison froide, ils échelonnent leurs mouvements autour des grands lacs, dont le Horo et le Fati constituent les grands pôles d'attraction et de regroupement. En saison chaude, c'est la transhumance dans les bourgoutières du lac Débo, du Gourma et du Macina, centres de rassemblement annuel des troupeaux Fulbe.

Ce retour dans la bourgoutière donne lieu à des manifestations et grandes fêtes au cours desquelles un jury procède au classement des meilleurs animaux. Le circuit de ferme avec le retour en juin–juillet dans le Tilemsi et les Daouna. C'est la grande transhumance. La plupart de ces troupeaux appartiennent aux Fulbe de Niafunké, Tonka, Atta, Diré, Goundam, Saréyamou, etc. Il existe une petite transhumance occasionnelle sans grande amplitude, visant à présenter le bétail dans un environnement aux potentialités fourragères relativement pérennes; par exemple, suivant les itinéraires de parcours, on peut distinguer les circuits suivants: Lac Faguibine; Lac Télé-retour; Lac Horo; Lac Fati-retour.

Les trajets de transhumance sont plus ou moins immuables et les Fulbe restés au village savent à peu près où trouver les troupeaux transhumants, ce qui permet d'expédier les vaches taries ou nouvellement achetées; on récupère également celles qui ont vêlé au cours de la transhumance et les bêtes destinées à la vente.

Système d'Élevage Sédentaire

Depuis les années 1940, les populations sédentaires ont considérablement augmenté leurs investissements dans l'élevage (Marty, 1986). C'est un élevage de terroir, pratiqué par les agriculteurs, les commerçants et les Fulbe sédentarisés. Les animaux demeurent toute l'année au village.

Le gardiennage se fait, généralement, par un système ingénieux de roulement: Chaque éleveur est astreint à un jour de surveillance. Cependant, dans certains villages, tout le troupeau *(diawdi, Songhay)* est confié à un berger Pullo ou Bella, moyennant une rémunération en mil ou en argent. Souvent, une fois les récoltes terminées, il arrive que les villageois récupèrent leurs troupeaux pour assurer eux-mêmes le gardiennage. Les vaches sont traites le matin avant leur départ aux pâturages; elles reviennent pour la traite du soir et passent la nuit au village. Celles qui sont en fin de lactation retournent à la transhumance. Ce système d'élevage est très développé aux alentours des lacs et de la vallée du fleuve. Notons que depuis la sécheresse, de nombreux fonctionnaires, et même des militaires, sont devenus propriétaires de bovins au point de concurrencer les éleveurs professionnels. Le bétail va-t-il changer de main ?

Les Espèces Animales

La région lacustre, comme l'ensemble de la zone sahélienne, est peuplée par plusieurs races d'animaux: bovins, ovins et caprins, asins, équins et camélidés. On peut noter que de nombreuses autres espèces sont représentées malgré des conditions naturelles parfois très défavorables et contraignantes à leur survie. Le nombre exact des animaux dans la région lacustre n'est pas connu de façon certaine, en raison des mouvements de transhumance.

Les chiffres dont on peut disposer proviennent de deux sources. La première est d'ordre purement administratif et se fonde sur les calculs de l'impôt par tête de bétail. La seconde est constituée essentiellement par les données statistiques des services de l'élevage, sur la base du nombre d'animaux vaccinés par secteur. Les estimations de celle-ci sont plus proches de la réalité que celles de l'administration, faussvés dans une large mesure par la fraude fiscale (Tableau 1).

Le Rôle Économique et Social du Bétail

La finalité de l'élevage réside dans son rôle économique doublé de considérations sociales et religieuses. Le bétail représente un signe extérieur de richesse et entraîne considération et respect. C'est aussi un moyen d'investissement certain car, en cas de difficultés, on vendra une bête, sans compter les produits laitiers, la laine et les peaux. Cependant, la motivation principale demeure la possession de nombreux troupeaux.

Les Considérations Sociales et Religieuses

Les Prêts

C'est une pratique courante dont le but est le renforcement des liens familiaux. Chez les Fulbe, par exemple, deux systèmes sont encore observés

- *le douncal* consiste à céder une génisse à un parent, un ami ou même un nécessiteux. Celui-ci conserve le droit de gestion et de jouissance sur toute la descendance de la génisse,
- *le birnul* n'accorde qu'une jouissance à durée déterminée: un mois, si la vache est à son premier vêlage et 15 jours, si elle est à son second vêlage.

Il est à signaler que ces traditions sont en voie de disparition.

Les Prélèvements

Le plus important est la *Zaka*, prélèvement religieux dont les origines remontent à la Dina. Son paiement est proportionnel à l'importance numérique du troupeau. Il est de l'ordre d'un taureau sur 30 têtes ou une génisse sur 40 têtes. Cette tradition est de moins en moins observée, en raison des pertes importantes subies par le troupeau.

Toutefois, le bétail est et demeure un capital pour faire face à certaines circonstances : mariage, baptêmes, circoncision, fêtes religieuses (Tabaski et Ramadan), honneur à un hôte, etc.

l'Exploitation Économique

Le lait et le beurre sont généralement consommés par les éleveurs et les membres de leur famille: l'offre sur le marché est infime, il en est de même pour les cuirs et les peaux conservés pour les besoins personnels; seuls les bouchers livrent au marché ceux provenant des animaux

Tableau 1. Estimation des effectifs d'après le service de l'élevage de Niafunké (1986 et 1982)

Cercle	Bovins	Ovins-caprins	Equins-asins-camelins	UBT
Diré	7177	46,688	1115	11,183
Niafunké	62,400	580,200	1624	109,574
Goundam	42,746	57,828	7908	46,301
Total 1986	112,400	684,716	10,657	167,052
Total 1982	227,400	1,162,400	66,000	402,695

abattus. Mais au-delà des conflits et des antagonismes, les relations autrefois symboliques subsistent encore entre éleveurs et agriculteurs. De mars à juin, les éleveurs troquent les produits laitiers contre des céréales, instaurant ainsi une sorte de relation de clientèle et de complémentarité avec les riverains. C'est aussi le moment des paiements pour les contrats de gardiennage et de location des vaches laitières.

La commercialisation du bétail est effectuée exclusivement par des intermédiaires locaux (les Diawambé) en relation avec les marchands spécialisés dans l'exportation. Les principaux marchés ont lieu une fois par semaine à Tonka et à Léré. De par leur caractère, il s'agit là de marchés de collection, alimentant les exportations vers le Burkina, la Côte d'Ivoire. Pour desservir les régions plus au sud, citons les marchés de bétail de Saréyamou et de Saraféré; ces derniers, en raison de voies d'accès limitées par la crue, ont un caractère plutôt local et saisonnier. En plus des marchés évoqués ci-dessus, mentionnons aussi ceux, moins importants, de Diré, Goundam et Niafunké. Ils répondent essentiellement aux besoins locaux.

Forces et Faiblesses de l'Élevage

L'une des faiblesses majeures de ce système d'élevage réside dans son caractère sentimental, qui consiste surtout à posséder un très grand nombre d'animaux, plutôt que de produire de façon optimale. C'est, dit-on, à l'importance du troupeau que l'homme et son importance sociale sont évalués. Ceci semble confirmer la thèse propagée, qui consiste à dire que la dégradation de l'environnement est due essentiellement au surnombre dont les conséquences, en terme de surpâturages, sont hélas bien connues. En outre, il s'agit aussi d'un élevage qui s'appuie sur des structures sociales féodales, avec bien souvent des relations maître-esclave, en particulier chez les Fulbé et les Touareg. Quant à son coté positif, il repose sur un souci de conservation et de protection durables des ressources; car le droit traditionnel interdit en principe toute forme d'exploitation abusive des pâturages et du sol. Mais malheureusement, cette législation a été abolie, d'abord par l'administration coloniale en 1942, avec la mise en valeur des terres du lac Horo par l'Office du Niger, et ensuite par l'Etat malien en 1960. De facto, le droit traditionnel n'est plus respecté. Ainsi, éleveurs et agriculteurs sans se soucier de la pénurie des ressources naturelles, abusent de la libre utilisation des terres et des pâturages garantie par la loi.

En conclusion, l'économie pastorale reste dépendante des variations et de la rareté des pluies et des crues de Issa-Ber. Les espèces élevées sont assez variées et bien adaptées aux contraintes physiques. Avant la grande sécheresse des années 1970, les effectifs des troupeaux, depuis la période coloniale, se sont considérablement accrus dans la région comme le soulignent de nombreux rapports et études (Eaux et Forêts de Tombouctou, 1974, 1985; Chevalier, 1932; Clauzel, 1962). Cela est dû, semble-t-il, à une série de facteurs importants: la paix et la sécurité instaurée (plus de rezzous), les campagnes régulières de vaccination et la multiplication des forages, mais surtout à une longue période de pluviométrie et de crue favorable. En revanche, depuis les récentes sécheresses, il s'est crée un déséquilibre constant entre la charge des effectifs et le potentiel pastoral, le résultat de la dégradation des pâturages de brousse et de la disparition d'un nombre important de bourgoutières dans la vallée. Les conséquences se sont traduites par une modification totale des systèmes traditionnels d'élevage: dépérissement du nomadisme par la réduction de l'amplitude des distances, désorganisation du mode de transhumance, tentative de sédentarisation avec reconversion à l'agriculture et/ou abandon de la région par de nombreux éleveurs, apparition d'éleveurs nouveaux (commerçants, fonctionnaires y compris certains agriculteurs et bella), etc. Au total, les troupeaux sont toujours soumis au rythme de la crue et aux incertitudes des pâturages, créant une âpre compétition entre les collectivités locales pour l'usage des points d'eau, des bourgoutières et les rares terroirs agricoles capables d'assurer des rendements assez convenables. A notre avis, dans cette région, sans chercher à minimiser l'impact du surpâturage sur la dégradation de l'environnement, la part des variations hydro-climatiques est à placer au premier plan.

Nouvelles Tendances Socio-Économiques et Culturelles

Nous l'avons vu plus haut, les sécheresses antérieures ont pu être compensées grâce à la flexibilité dans le temps et dans l'espace des systèmes pastoraux, ainsi que des systèmes d'échanges entre les différents groupes socio-économiques. Mais depuis la sécheresse des années 70, ces stratégies de subsistance savamment élaborée le long des siècles, ont vu leurs bases socio économiques et culturelles complètement bouleversées. Ce chapitre se propose d'examiner les mutations survenues et les nouveaux comportements vécus à l'occasion du phénomène.

Structures Socio-Politiques

Socialement, les sociétés pastorales Touaróg et Fulbé sont bien structurées et surtout très hiérarchisées.[2] Dans l'ensemble, la configuration

[2]Le Group Targui est structuré de façon suivante: les nobles guerrier (Imajeghen, Imochagh), les marabouts (Ineslemen, Alfaqiten), vassaux tributaires (Imrad), les artisans (Ineden), au bas de l'echelle, les esclaves (Iklan).
— Le groupe peul est organisé comme suit: les nobles (Arbe, Jowro, Modibaabe, Fulbé-Wodabe), les castes ou artisans (Waylube, Maabuube, Gargasaabe, Lawbe, Wammbaybe), les esclaves (Rimaybe).
Dans cette classification les eclaves affichent la classe de leurs maîtres.

socio politique a survécu à la sécheresse. Ainsi, sur le plan des structures sociales, la hiérarchie classique est demeurée presque la même, avec la distinction sociale fondamentale entre nobles, vassaux de bas statut, artisans et captifs. Cependant, dans la pratique, sous les coups d'un certain nombre de facteurs (valeurs extérieures introduites par les services administratifs, scolarisation et émigration), dont les récentes crises climatiques, les rapports maîtres-esclaves connaissent une profonde détérioration. Les privilèges, qui permettaient aux premiers de vivre décemment, ne sont plus maintenus depuis la disparition du cheptel.

En milieu Targui, les *Imrad* (vassaux) et les *Iklan* (esclaves) n'acceptent plus de souffrir du partage du troupeau avec les maîtres *Imochagh*. La chute de ces derniers n'a jamais été aussi catastrophique qu'actuellement, avec la sécheresse persistante. Au cours des années 73–74 et 84–85, on a pu constater que le plus grand nombre de ceux qui mouraient du sinistre, étaient des nobles. Les rescapés ne doivent leur survie que dans l'exercice d'activités pour lesquelles, il n'y a pas si longtemps, ils éprouvaient de la répugnance: agriculture, pêche, artisanat, jardinage, mendicité, etc. En revanche, les *Imrad* et les *Iklan,* habitués aux durs travaux n'ont pas eu de difficultés à se réadapter à la nouvelle situation engendrée par la sécheresse.

Dans l'ensemble, le système socio-économique fondé sur la cellule familiale (la tente) a renforcé l'individualisme et la propriété familiale.

Les Fulbe eux aussi n'ont pas réussi ce passage sans difficultés majeures. Traditionnellement, transhumants et semi-sédentaires, ils ont vu leur espace pastoral réduit au détriment des cultures irriguées en lieu et place des bourgoutières. Les Dioro (propriétaires des terres) ont profité de cette situation de crise pour renforcer leur position sociale et consolider leur emprise sur les terres de la vallée. Les Fulbe rouges, brutalement démunis à la suite de la perte du cheptel, sont prêts à s'adonner à n'importe quel travail. Dans leurs rangs, nombreux sont ceux qui, n'ayant plus le choix, sont passés du statut de grands éleveurs à celui de bergers pour les agriculteurs ou les nouveaux éleveurs des villes. D'autres ont définitivement quitté la profession pour fuir à l'extérieur (exode à l'étranger, vers les villes et les villages). Toutefois, ceux qui sont restés tentent tan bien que mal de faire de l'élevage dans leur propre milieu et/ou de diversifier leurs activités et sources de revenus (en plus de l'élevage, cueillette, transport, petits travaux, commerce, agriculture, etc.). Dans leurs rangs on trouve la propension la plus forte en direction d'une certaine sédentarisation et de reconversion à l'agriculture ou au commerce du bétail.

En milieu Targui, c'est aussi le cas des anciens esclaves quittant leurs maîtres dans le dénument ou, plus récemment, de tous ceux dont les moyens de subsistance ont été sapés par la sécheresse et qui acceptent de se lancer dans toutes sortes d'aventures. De même dans les couches superiéures de la société, les nobles, qui n'ont pu s'adapter aux changements, assistent au phénomène avec regret et amertume; beaucoup se sont résignés à vivre de mendicité ou de parasitisme autour des villes, autre manière de faire face à la crise.

Chez les Fulbe, en particulier, cela a eu pour conséquence la démystification de la bomanie (des Fulbe), suivie de la disparition même de certains rites pastoraux. Par exemple, à l'heure actuelle, le concours annuel organisé pour couronner les meilleurs éleveurs de l'année et discréditer les derniers, a perdu son caractère solennel de jadis. Dans certains endroits, il a tout simplement disparu de la tradition pastorale. Le *dégal* ou *diaral* (traversée des animaux) qui a lieu à Diafarabé une fois par an n'est observé que pour ses aspects folkloriques. Le caractère d'émulation et de rivalité qu'il suscitait chez les grands bergers, n'est plus qu'un vague souvenir du passé; ce qui explique du coup le manque de performance au niveau de la production animale.

Quant aux couches de "castes": Mabo, Diogoramé, ils se sont très vite accoutumés aux nouvelles circonstances de vie. L'indépendance vis-à-vis des nobles leur a permis d'initier leurs propres projets ou entreprises.

Signalons que certains marabouts ont essayé de mettre cette situation à profit, pour réconforter leur position spirituelle. Ils mystifient la sécheresse et la présentent aux profanes comme les indices d'un *"châtiment divin"* ou comme une manifestation de la fin du monde. Néanmoins, ceux pour lesquels la chance n'a pas souri lors des "rogations" pour faire tomber la pluie, ont en même temps perdu la confiance populaire. Ils voient ainsi leur puissance et efficacité réduites.

Tout cela signifie-t-il, qu'à l'heure actuelle, les activités économiques et même culturelles, ne peuvent plus être attribuées selon une appartenance ethnique ou de classe sociale spécifique. Ainsi, suite à la décimation du cheptel, de nombreux éleveurs se sont reconvertis en agriculteurs, pêcheurs, artisans, commercants, etc.; ces derniers à leur tour se sont transmutées en éleveurs.

Aussi, l'image typique selon laquelle la femme, dans cette région, ne travaille pas, mais dirige les travaux ménagers a-t-elle disparu (à l'exception des couches aisées, marabouts, chefs traditionnels, etc.)?

Aujourd'hui, plus que jamais, la femme participe à tous les travaux quelque soit son statut ou son rang: travaux des champs, construction des cases, ramassage de bois, transport de l'eau, confection des produits de l'artisanat, entre autre. Avec l'appui et l'encadrement des ONG et services techniques, le jardinage et le petit commerce sont devenus pour elle les principales sources de revenus.

La sécheresse a, de ce fait, contribué à l'alourdissement des tâches quotidiennes de subsistance de la femme.

Transformations Morales et Culturelles

Comme nous venons de le voir, la sécheresse a entraîné une désarticulation des structures sociales traditionnelles. Cette situation s'est accompagnee de nombreuses mutations par rapport a certaines grandes valeurs comme: Les distinctions honorifiques témoignées aux nobles, le sens aigu de l'honneur et de la dignité. En même temps, on assiste au dépérissement des autres valeurs comme: l'hospitalité, les largesses, la solidarité. En revanche, l'individualisme, l'esprit mercantiliste et la foi en l'argent gagnent de plus en plus d'adeptes.

Les infrastructures d'enseignement et de santé, dans certains centres sont pratiquement abandonnées, à la suite du dépérissement des ressources de l'Etat, le rejet de l'école et le sous-encadrement. Ainsi, le pourcentage d'analphabète se situe autour de 95% dans les villages, et la situation alimentaire et sanitaire n'est guère meilleure. Traditionnellement, les Fulbe et les Touareg se nourissent de produits laitiers: viande, lait et beurre. Depuis la sécheresse, l'alimentation, tout en comportant une importante proportion de céréales, demeure irrégulière, peu abondante et inadaptée à l'organisme. Cette rupture d'équilibre est à l'origine de l'état de morbidité observé dans les camps des sinistrés.

La campagne s'est vidée de sa population. Dans les villages et campements confrontés à un stress permanent, les réjouissances populaires ont connu une certaine régression. Ainsi pendant plusieurs années on a peu chanté et dansé le soir.

Mutations Socio-Économiques

Les variations climatiques ont nettement favorisé et entretenu l'émergence de nouveaux comportements socio-économiques.

Les relations symbiotiques ou d'échanges, de jadis, en vue de garantir à long terme la coexistence fondée sur l'intégration de l'agriculture et de l'élevage, se sont transformées en relations de conflits et de concurrences, à travers des facteurs suivants:

- accroissement de l'agriculture au détriment des bourgoutières;
- restriction des droits de pâturages,
- commercialisation des cultures fourragères (bourgou);
- introduction d'intrants modernes au détriment des contrats de fumure;
- intégration graduelle de l'agriculture dans le marché...

Avec la paupérisation généralisée, les anciennes solidarités fondées sur tout un réseau de dons et de prêts d'animaux entre amis, clans ou en directions des pauvres, ont perdu de leur importance. Ce mouvement traduit une fragilisation accrue des systèmes de production aggravée désormais par la nécessité de produire pour vendre. L'échange marchand tend donc à se substituer aux anciennes formes de complémentarités entre agriculture et élevage. Dans les rapports de production maîtres-esclaves, le travail contractuel de type salarial se développe au détriment des vieilles pratiques comme: le métayage, le fermage et les travaux domestiques.

L'élevage tend à se concentrer dans les mains de nouveaux groupes sociaux ne représentant plus les éleveurs traditionnels. Les nouveaux éleveurs (commerçants, fonctionnaires et quelques agriculteurs des centres urbains et semi-urbains) pratiquent l'embouche paysanne ou possedènt de petits troupeaux soutenus, essentiellement, par les sous-produits agricoles (enrichis à l'urée ou à la mélasse) et les cultures fourragères issues des exploitations agricoles.

Il s'agit d'un élevage évoluant vers un type mocierne, utilisant le crédit agricole pour procéder à des investissements financiers importants. C'est, certainement, les signes précurseurs d'un élevage intensif, avec des travailleurs salariés et qui portera surtout sur la rentabilité et le rendement.

Actuellement, en prévision d'un éventuel accroissement de la population animale, dans cette région à écologie vulnérable, on assiste à l'apparition des nouvelles réactions et stratégies:

- modification profonde de la structure du troupeau par le déstockage des mâles;
- transfert d'animaux dans les zones plus méridionales;
- introduction de l'embouche paysanne aussi bien dans les zones encadrées par les opérations de développement que par des particuliers;
- éclatement de la cellule familiale suivi de celui des grands troupeaux entre les membres d'une même famille, afin de minimiser les pertes et faciliter les déplacements tous azimuts.

La migration des jeunes, en vue de trouver du travail, ne faisait pas partie de la tradition régionale, pourtant, maintenant, la détresse pousse même les hommes et femmes mariés à émigrer vers le marché du travail. Les exodants au contact avec l'extérieur ont acquis de nouveaux savoir-faire (en mécanique, maçonnerie, menuiserie, irrigation, etc.) et développé une logique marchande en quête de plus en plus de revenus monétaires et d'une autonomie de décision par rapport à leurs parents.

Enfin, l'artisanat local, pour avoir souffert de la rareté des matières premières (bois, peaux, cuirs, etc.) ne joue plus pleinement sa fonction de fournisseur d'outils pour l'agriculture et l'élevage, et l'étendue du commerce régional et local a largement diminué. Les articles produits (nattes, éventails, bijoux, etc.), en raison de leur aspect grossier (destinés au tourisme), n'offrent que des prix dérisoires, à 50% de leur prix ordinaire.

Sous les effets des variations climatiques, les pasteurs Fulbe et Touareg, pour survivre, ont adopté de nouvelles carrières et abandonné certaines valeurs incompatibles avec la situation actuelle des conditions de vie. Ils s'adonnent alors à tout un ensemble d'activités, dans le seul but d'éviter la dépendance vis-à-vis des variations climatiques imprévisibles.

En conclusion, sans chercher à tout mettre au compte de la seule sécheresse, disons qu'elle a largement contribué aux transformations socio-économiques et culturelles des communautés pastorales Fulbe et Touareg de la région lacustre de l'Issa-Ber. A partir des faits que nous venons d'évoquer, on voit que la sécheresse n'a laissé aucune catégorie sociale totalement identique à elle-même. Elle a mis à nu la vulnérabilité des systèmes pastoraux actuels et l'émergence de nouveaux clivages sociaux, à la suite du dépérissement progressif du pouvoir politique et économique des anciennes couches supérieures de la société. Aussi assiste-t-on à la montée en puissance de nouveaux groupes d'éleveurs très favorables aux changements, et prêt a tirer des leçons des sécheresses antérieures.

Les populations pastorales sont aujourd'hui géographiquement, économiquement et culturellement marginalisées. Elles ont tout perdu y compris leur identité culturelle. Pour assurer à long terme l'équité du développement économique et social dans cette région qui nous préoccupe, toute stratégie future de développement en faveur des éleveurs doit tendre expressément à atténuer la pauvreté et à améliorer la répartition juste et rationnelle des ressources naturelles existantes et des revenus. Dans cette optique, nous suggérons les actions suivantes:

- Trouver aux problèmes fonciers des solutions originales exemptes de toute partialité ou de tout subjectivisme. Ces solutions doivent être applicables technologiquement, économiquement et sociologiquement, afin d'aboutir à des codes pastoraux viables.
- Prévoir un système d'alerte précoce pour permettre aux éleveurs de prendre leurs dispositions à temps utile.
- Améliorer les systèmes de production pour évoluer vers de petits troupeaux à haut rendement;
- Faire participer les éleveurs aux actions d'aménagement et de gestion des parcours par l'élaboration de cahiers de charges;
- Vulgariser la production et la conservation du fourrage et des résidus des récoltes;
- Améliorer la couverture sanitaire du cheptel;
- Développer l'embouche dans les zones à dominance agricole;
- Intensifier la recherche sur les systèmes de production;
- Développer l'intégration agriculture-élevage.

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Social Aspects of Mid-Continent Droughts (The Aral Sea Region, etc.)

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The to be climate change is known to lead to significant changes in the natural environment and social implications many of which are of a substantially negative character.

The report[1] includes sections describing the potential impacts of climate change on: agriculture and forestry, natural terrestrial ecosystems, hydrology and water resources, human settlements, energy, transport, industry, human health, and oceans and coastal zones, as well as seasonal snow cover, ice and permafrost.

Estimates based on possible temperature increase in the next several decades indicate that some regions with unstable moisture will become drier[1, 2] and that this can result in higher land degradation and yield loss. The humid areas will be more saturated with moisture, and the frequency and intensity of tropical storms will be higher. The frequency and nature of extreme impacts on agriculture caused by floods, stable droughts, forest fires, and agricultural plant pests will change. The duration of the warm season will increase in many areas.

The calculated impacts on the potential yield with a doubling of CO_2 (in 30–60 years) showed that in northern mid-latitudes the summer droughts can reduce the productivity potential by 10–30%.

In tropical and subtropical regions where most developing countries are located significant climate change is predicted. It is noteworthy that alongside the long-term droughts in the Sahel, Ethiopia, and in a number of other African countries attention should be given to El Niño of 1982–83 which, according to the opinion of scientists, led to the drought in Brazil, Australia, India, and a part of Africa at that time.

Major vegetation zones will be subjected to substantial impacts, and this will be reflected in vegetation communities and their respective animal populations. The rate of climate change may be so rapid that some ecosystems may not be able to adapt to new climate conditions. Some species might completely disappear, and that will naturally lead to a decrease in biodiversity.

In some regions the soil moisture may drop, particularly in areas where moisture deficit in soils is observed even now, e.g., in Africa. A 1°C to 2°C air temperature increase coupled with a simultaneous 10% reduction in precipitation could produce a 40–70% reduction in mean annual river runoff. Such runoff reduction can markedly affect the agriculture, water supply and hydropower. As for potential changes in water resources in the future, it could be said that the situation is very uncertain. Therefore, additional comprehensive studies on this problem, which is very important for the region, are required.

From the viewpoint of scales and scopes of consequences droughts and desertifications over large areas deserve particular attention. Droughts and desertification result in heavy geophysical, ecological and social consequences. Arid zones of the Earth cover large territories. The territories of more than 100 countries subject to droughts over many billions of years are much damaged by them (Fig. 1[2]). There is no doubt, that droughts are connected with climate, and climate change effects the drought.

Fig. 2 shows the change in the grain yield (centner per ha) in space over the former USSR territory (the increase is due to the improved farm technology)[3]. A solid curve denotes real values, and a dashed curve—the yield under favourable conditions (good precipitation). It follows from the Figure that certain droughts that frequently occurred over the former USSR territory reduced significantly the yield. In favourable years the yield was recovered. However, in recent years multiyear deviations from the norm are recorded. A trend is observed which must be characteristic of desertification in a number of regions of a "risk" agriculture.

The drought must be an element of the climate in the region while desertification is a process when aridity of the territory intensifies (both from

[1]Climate Change (1992) The Supplementary Report to the IPCC Impacts Assessment Report prepared for the IPCC by Working Group II (Chair Yu. A. Izrael), Eds. Mc. G. Tegart, Sheldon G. W.

[2]*Climate Change Bulletin*. Issue 3. 2nd Quarter 1994, pp. 4–5.

[3]"Anthropogenic Climate Changes" (Edited by Budkyo M. I. and Izrael Yu A. L.) *Gidrometeoizdat*, 1987.

the viewpoint of its frequency and intensity of the phenomenon).

Desertification is determined in work[4] as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climate variations and human activities". I would add into the first part of the determination, "and increasing of frequency and intensity of droughts", and into the second part, "and climate change".

Many examples demonstrate that droughts and desertification are interconnected and it is caused by natural as well as anthropogenic processes of global, regional and local scales. The importance of the drought control raised an urgent problem of developing "Desertification Convention". The problem is doubtless of global as well as local significance.

The Sahel zone spreading from the Atlantic coast of Senegal to the Indian Ocean coast of East Africa presents the largest zone of desertification and long-term droughts.

The overall stand plant store of the biomass in undisturbed natural conditions varies within 0.5–2.5 t of a dry substance per ha.

The desertification here presents a continuous menace and life is almost constantly under stress state. Scarcity of available water is a main obstacle for agriculture.

This refers both to seasonal distribution within a year and to unpredicted implications of long-term droughts (of several years). Social consequences of such phenomena are sufficiently obvious.

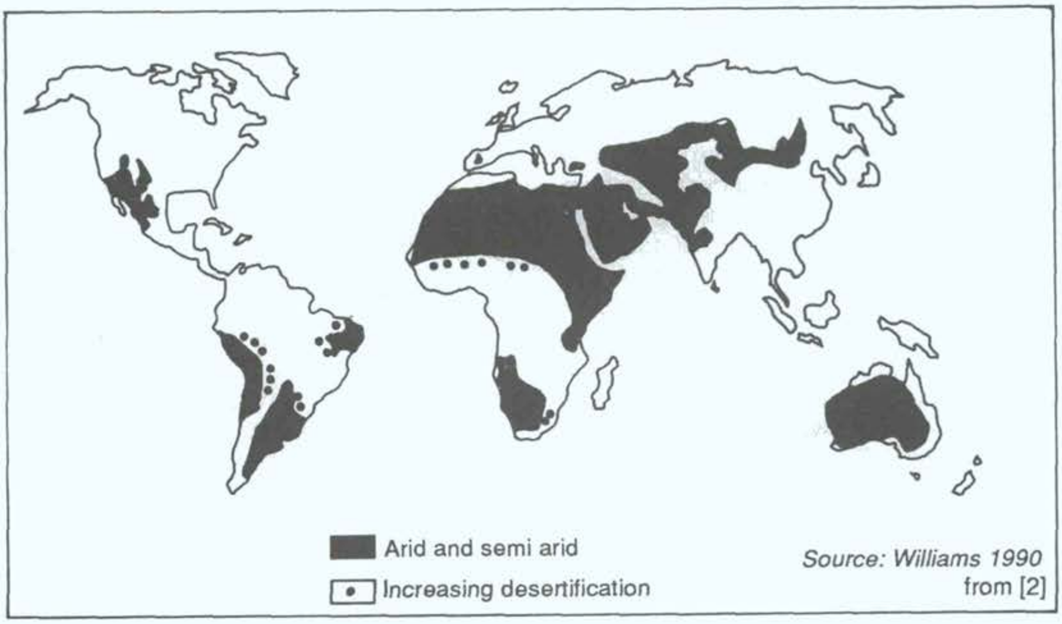

Fig. 1. Arid and semi-arid zones.

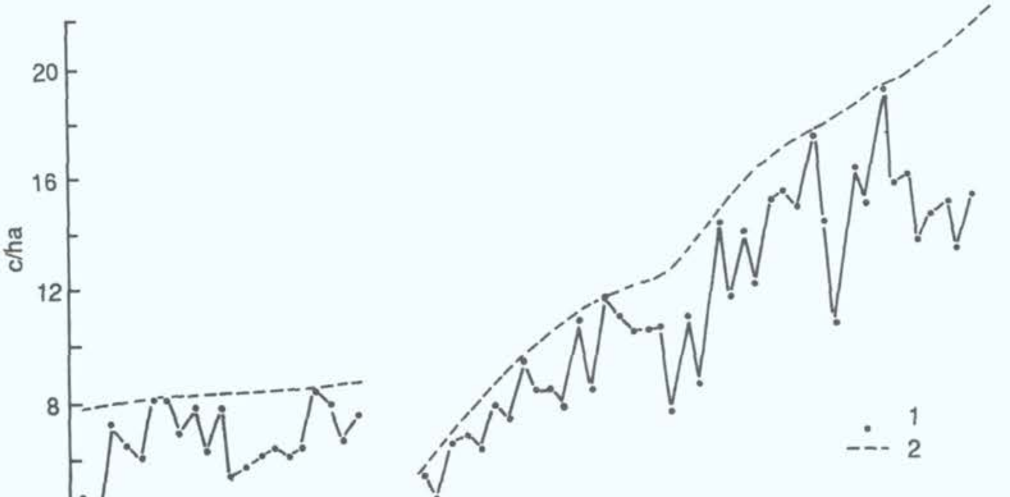

Fig. 2. The change in the grain yield in time over the former USSR territory.

[4] *Impact* NII, Dec. 1993, p. 14.

In this region one should single out the tragedy of Lake Chad which is disappearing due to natural and anthropogenic impacts.

The tragedy of the dried out Aral Sea in Central Asia over a former USSR territory (now a territory shared by three new states: Kazakhstan, Uzbekistan, Turkmenistan) is the other example of intensive development of droughts and desertification produced by natural and anthropogenic impacts of a various scale with particularly heavy social implications.

Let us dwell on a problem of mid-continent droughts, desertification and social implications taking the vast Aral region as an example. It manifests the entire complexity and evidence of natural and anthropogenic impacts, feedforward and feedback between impacts and consequences.[5]

The Aral Sea and the adjoining regions (Priaralje) are located in the northern Central Asian economic region. The total area of the Priaralje is 473.7 thousand km^2, making the following areas in the states:

Uzbekistan (Karakalpak ASSR and Horezm region)	172.0
Turkmenistan (Tashauzsk region)	73.6
Kazakhstan (Kzyl-Ordinsk region)	228.1

In 1985 the population number in the Priaralje region was above 3 million people. The network of urban points included by 1 January, 1985, 20 towns and 34 settlements of an urban type with the population of 1.4 million people. Nowadays the irrigated lands in Karakalpak made 450 thousand ha.

Before 1960 the Aral Sea received with the Amu-Darya and Syr-Darya waters 33–64 (on average 50) km^3 of water per year; the sea level was stable. The deltas of these rivers were large oases of life-forests, herbaceous plants, agriculture, huge amounts of wild and domestic animals (Table 1).

Since 1960 new irrigated lands started to be introduced in the upper Amu-Darya and Syr-Darya rivers—the water inflow into the sea began to drop sharply due to the combination of the following factors of anthropogenic and natural character, local and global scale:

1. Anthropogenic activity (reducing of the water).
2. Droughts during the period of 1960–1990.
3. Climate change
   (a) Regional (anthropogenic), and
   (b) Global.

In Table 1, Fig. 3a and 3b changes of main characteristics of the Aral Sea, and the inflow of water into the sea over the last 30–35 years are shown. These changes were accompanied by the Aral Sea region desertification and other unfavourable conditions.

In the recent years in Priaralje, especially in Karakalpak ASSR, Kzyl-Ordinsk and Tashauzsk regions an extreme socio-economic, ecological and sanitary-epidemiological situation is formed, which threatened the human health.

According to the former USSR Ministry of Health the total population mortality in the Karakalpak ASSR increased over the last 20 years. The malignant tumour disease level has increased. The infectious diseases, particularly enteroidea group increase.

The disappearance of natural floods of the Amu-Darya in their lower current, the drop of the Aral Sea level produced climate changes, progressive anthropogenic desertification of Priaralje, including aridisation and salinisation of the Amu-Darya and Syr-Darya deltas.

Because of the decreased input of the river water into the sea its level began to drop on a permanent basis. It became much pronounced after 1965. By 1986–1987 the Aral Sea level dropped almost by 12.5 m, and its mark nowadays is 40.5 m abs. The sea area reduced by 25 thousand km^2, or more than by one third. The water volume reduced by 640 km^3 or 60‰, the mean salinity increased 2.5 times and reached 30‰ and more (Fig. 4).

In 1987 so-called Small Sea was separated from the Aral Sea water area. Its water salinity will be above 29‰. Without the river water input the Small Sea can be dried up during the next two decades. By the year 2000 the Aral Sea level will drop to marks 35.5–34.5 m abs. and its salinity will raise up to 40–44‰.

The aridisation of the delta river sections is followed by the disappearance of water-stressed vegetation and the cessation of alluvial soil

Table 1. Aral Sea

	1960	1985	2000
Level	53 m	40.5 m	35 m
Input	33–64 (50) km^3/yr	0–10 km^3/yr	?
S	66,000 km^2	40,000 km^2	
V	1064 km^3	420 km^3	
Salinity	9.6–10.3‰ (g/l)	26–30‰ (g/l)	40–44‰ (g/l)
1961–1986	715 km^3		
Deficit	(anthrop. 560 drought 165)		

[5] *Meteorology and Hydrology* (Russia) No. 9, 1988, pp. 5–22. Yu. A. Izrael et al.

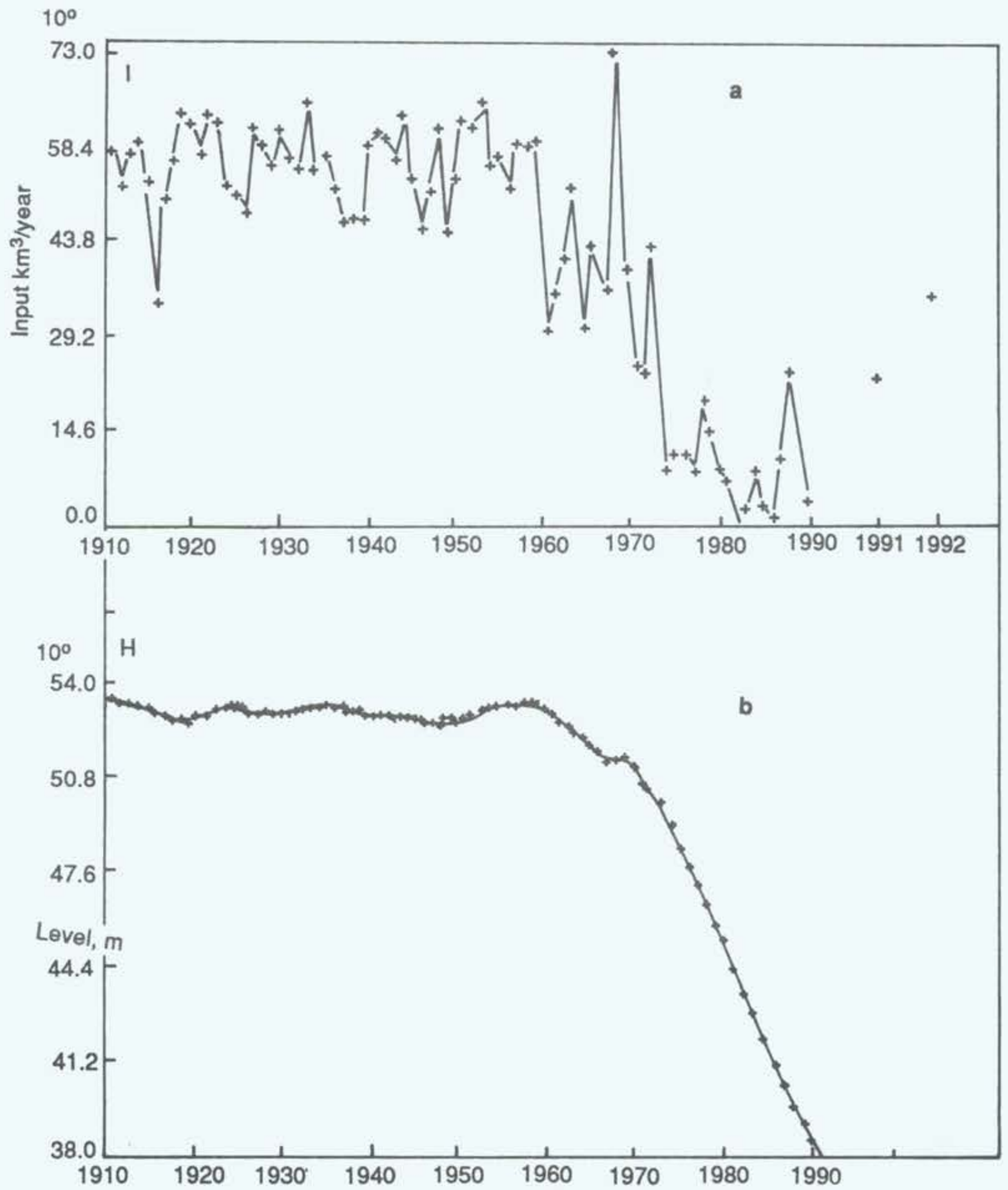

Fig. 3. Input into the sea (a) and Aral Sea (b) level.

formation. They are rapidly salinised and degrade. Only in the Amu-Darya delta and the area under cane reduced for the last 20 years from 550 to 20 thousand ha; more than 50 lakes have been dried up.

The aridisation has endangered the wildlife: Of 178 species of animals inhabiting these areas only 38 species are preserved by the present day. The musk-deer which had been used here as an important export good has almost totally disappeared.

Up to the recent time the Aral Sea has been a major fishery water-body in Central Asia and Kazakhstan. Most valuable fish species (goldfish, bream, volba, zherekh, etc.) in the amount of 40–45 thousand t/yr were caught here. Nowadays the Aral Sea has totally lost its fishery importance.

The dust is transported for 200 and more kilometres. In 60% of cases the dust fluxes move south-westward. According to preliminary assessments from 15 to 75 million t of dust are annually ejected into the atmosphere. Under present day conditions the total amount of salts deposited onto the surface in the Priaralje region is on the average 520 kg/ha, 340 kg/ha of the total are dry depositions and up to 180 kg/ha are deposited with atmospheric precipitation.

The degraded natural environment of Priaralje led to a necessity of providing the part of the population which had worked before in fishery, shipping and other traditional branches of the economy with work.

Thus the present-day natural situation in the region and its effect on socio-economic processes makes Priaralje a region of the extreme ecological state.

As a result socio-economic and environmental aspects of the problem of the environment in Priaralje (the Aral Sea) are very hard.

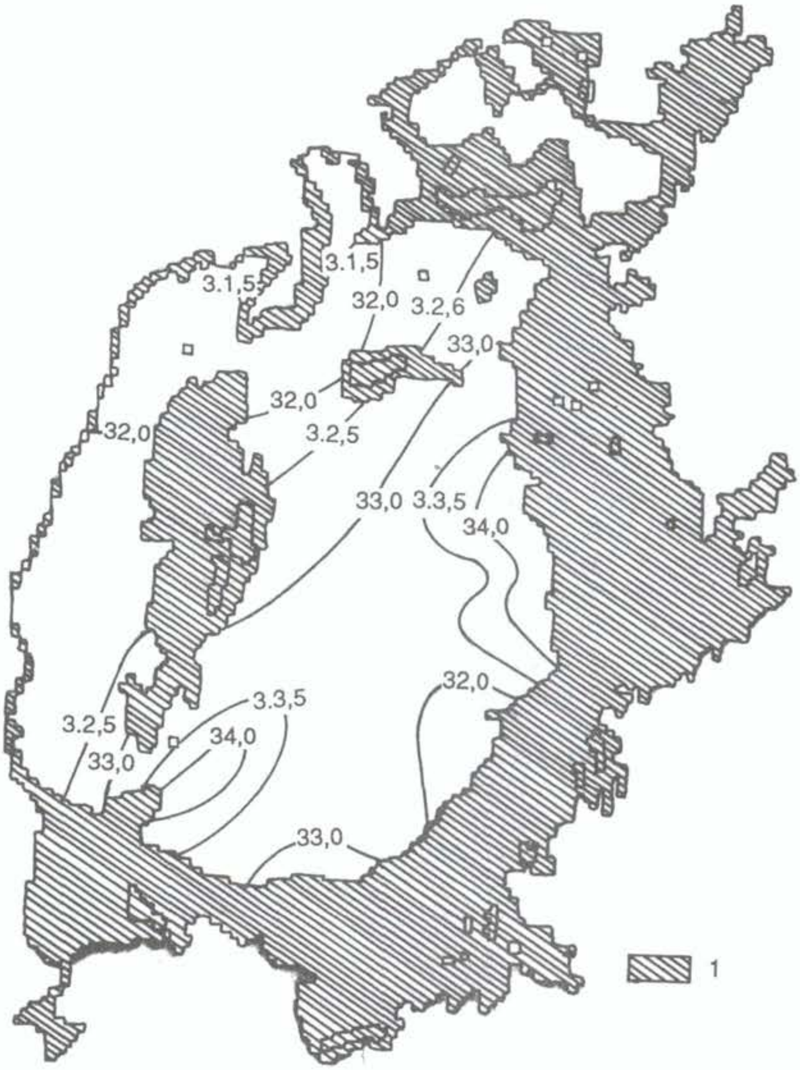

Fig. 4. Salinity of the Aral Sea waters (1990).

The Aral Sea region was damaged ecologically and socio-economically. The analogue does not exist in the human history: Something like that happened in the Lake Chad region though the scale of the anthropogenic impacts was much less.[6]

The aridised and dried up deltas and fluvial plain of the Amu-Darya caused the transformation of hydromorphous soils into automorphous (sand and solonchaks) soils over an area of more than 500,000 ha. These lands were supposed to be developed for agricultural purposes. Similar losses took place in the lower Syr-Darya, in the Kzyl-Ordinsk oblast. Desertification reduced the area of the best alluvial meadow (tugai) soils; over 20 years the area was reduced by 171 thousand ha (30%). The area of the meadow swamp soils suitable to be developed for rice reduced in the lower relief three times in 20 years. In total the losses of the land resources in the delta and fluvial plain of the Syr-Darya are also over 500 thousand ha.

The salt and dust blown by the wind from the dried up sea bottom to adjoining territories reduce the productivity of the pastoral and cultivation system.

Of a great concern is the increased amounts of salts in the atmosphere. According to some scientists even extremely fine fractions of salts in the air can sterilise the plant fruit organs and ruin their productivity (including cotton at a distance of a hundred kilometres).

The intensive salinisation produces a drastic reduction in the yield and both newly irrigated areas and already developed lands fall out of the production sphere.

The reduced pastoral productivity and forage capacity predetermines the possible decrease of the sheep head number in the Syr-Darya and Amu-Darya deltas. Particularly affected were forage lands in deltas with their specific ecosystems, e.g.; the losses produced by the reduced productivity of pastures whose area in the lower Amu-Darya is now 783 thousand ha.

[6] "Monitoring in the Water Catchment Area of the Aral Sea" (Edited by Monokrovich E.) *Gidrometeoizdat*, pp. 187–95; 1991.

Still higher economic losses are produced by reduced areas under haylands in the delta and fluvial plain of the Syr-Darya. For 20 years the area reduced 3.7 times—from 427 down to 115 thousand ha.

The reduced fish caught and volumes of the processed fish, manufacturing of other kinds of products, migration, an accelarated reduction of the sea sizes—all these things led to a sharp reduction in transportation volumes and losses in water transport.

Potential possibilities of using recreational resources of the Aral Sea are lost to a great extent.

And finally we should dwell on a problem of the deteriorated health of the population in Priaralje—diseases, negative migration processes. It is a main cause of the ever-increasing migration of the population; particularly substantial is migration from towns and town-type settlements—Aralsk, Mujnaka, Uchsaya.

Such are social effects of intensified droughts resulting from anthropogenic activity, climate change and its consequences.

Taking into account the fact that the ecological situation in Priaralje is determined by the water management conditions and trends in the economy development both in the entire Aral Sea basin and directly over its territory the recommendations proposed below and actions required to improve the ecological and sanitary-epidemiological situation in the region are given separately for the above territories.

It is reasonable to develop and realise before 2000–2010 an integrated long term scientific and technical programme of the socio-economic development of Priaralje (the "Priaralje" programme).

In the former USSR a special programme for management and saving the situation was developed:

1. Population health.
2. Water supply and sewerage system.
3. Industry and transport.
4. Agroindustrial complex.
5. Surface and underground water protection.
6. Transformation of the Aral Sea water area.
7. Fishery.
8. Eco-Socio-monitoring.

However the implementation of the programme is in a poor state because of the economic difficulties of the new states of this region. The international efforts should be applied to solve this very urgent problem.

Impacts of Climate Change on Coastal Communities: The Senegal Example

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With the Rio Summit in June 1992, climate change became one major concern of governments, planners and scientists. The World Coast Conference held in Noordwijk (The Netherlands) November 1993 was a unique opportunity for international and non-governmental organisations, national decision makers and scientists to make the point about the impacts of climate change on coastal zones and the ways to mitigate them (Intergovernmental Panel on Climate Change, 1994).

The purpose of this communication is to look at the possible consequences of climate change on Senegalese coastal communities. Rather than a specialist opinion, it is the advice of a scientist whose field of reflection has been enlarged by successive interdisciplinary IPCC meetings.

Coastal Population and Economic Activities

Data are issued from the last 1988 census results (Direction de la Prevision et de la Statistique, 1992 a–g).

Considering the population living in the littoral zone, that say between +6 metres and sea level, our estimations give a coastal population of about 3.45 million people in 1988 or 50% of the total population. A look at Table 1 shows the great disparities in the geographical distribution of the coastal population.

Towns with more than 100,000 inhabitants are located either on the coast (Saint Louis, Dakar, Rufisque) or inside the estuarine zones (Kaolack and Ziguinchor) (Fig. 1). These towns are colonial in heritage: Saint Louis and Dakar were capital cities of the West Africa French empire while Rufisque and Kaolack were major commercial cities, centralising the peanut trade. These towns have been chosen for their port facilities, reason why old towns like Saint Louis (Camara, 1968) and Rufisque (Dubresson, 1979) have been abandoned in favour of Dakar where the construction of a deep sea harbour began in 1862 (Seck, 1970). Apart from these big cities, we find smaller ones especially on the coast south of Dakar and in the Senegal and Saloum estuaries and also a number of small villages disseminated along the coast.

Table 1. Coastal population by region

Region/Dpt	Population (in 1988)	Density (people/km^2)	Population growth rate (%)	% of coastal population
Saint Louis				
Dpt of Dagana	285,879	46	2.57	8
Louga				
Dpt of Louga	195,320	35	3	6
Thies				
Dpt of Tivaouane	293,298	91	3	9
Dakar	**1,488,941**	**2707**	**4**	**43**
Thies				
Dpt of Mbour	280,424	175	3	8
Fatick				
Dpt of Fatick	208,481	64	1.7	6
Kaolack				
Dpt of Kaolack	299,738	160	2.6	9
Ziguinchor				
Dpt of Bignona	184,807	35		5
Dpt of Oussouye	37,098	42	2.6	1
Dpt of Ziguinchor	176,432	153		5

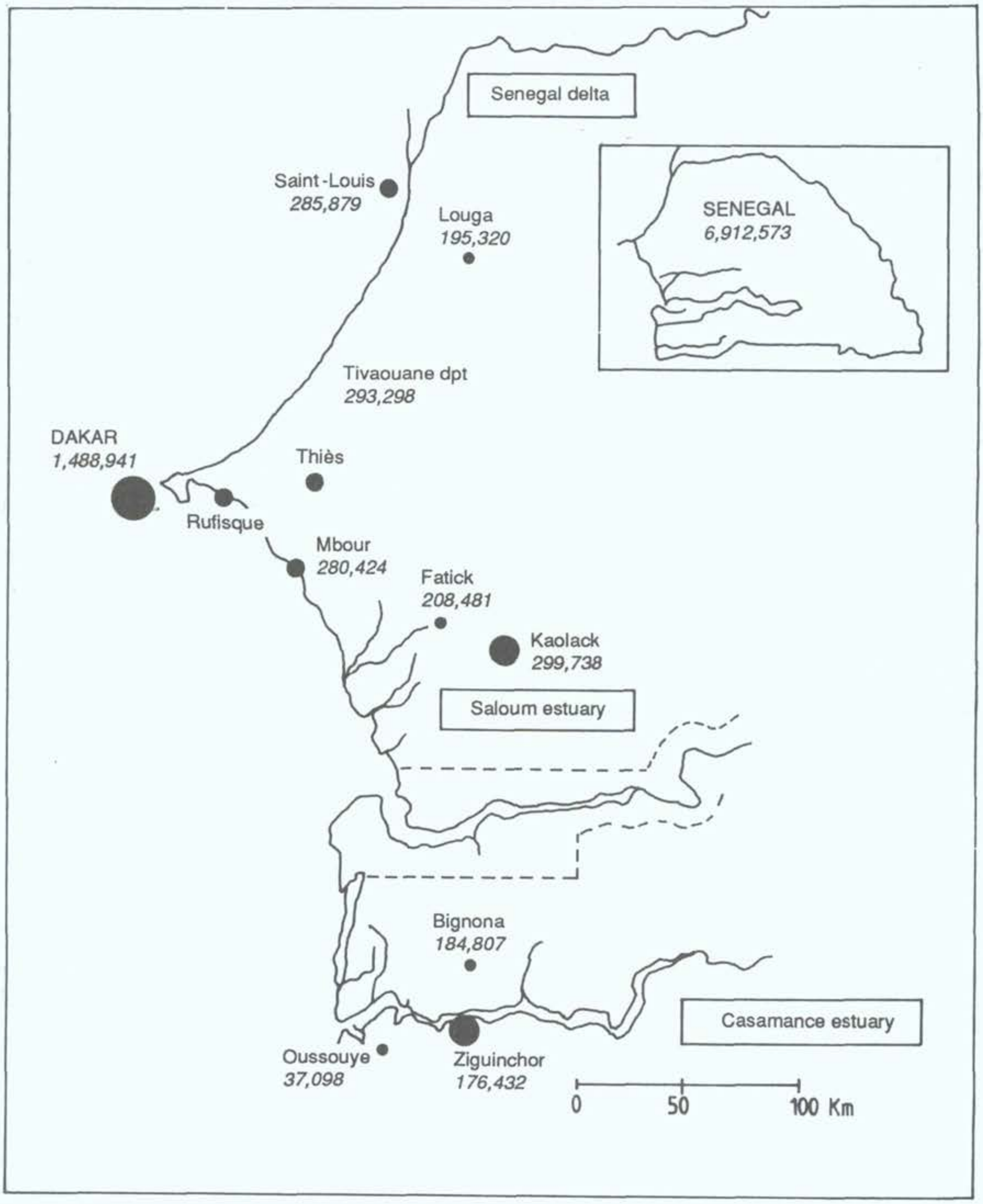

Fig. 1. Senegal. Main littoral towns and population (in 1988).

With the exception of the capital Dakar which concentrates 90% of the country's industry and most of the tertiary activities and where people have diversified occupations even though more than 24% of the population is unemployed, coastal population is involved in three main economic activities (Niang, 1990; Ba, 1993):

- Fisheries which are mainly artisanal (72% of the 1990 captures or 246,278 tons), industrial fisheries being concentrated in Dakar. This activity is exerted in the economic exclusive zone as well as in estuaries (Diouf et al., 1993). In 1990, it was the main activity for about 48,122 people (about 3% of the employed population). The great productivity of coastal waters depends on coastal upwellings. Due to seasonal changes in oceanographic conditions, fishermen migrate along the coast with two main temporary fishing centres: Kayar, north of Dakar, during the dry season and Mbour-Joal, south of Dakar, during the rainy season (Dione, 1986). It is important to note that fishing is the main activity of one ethnic group, the Lebou, who are the first inhabitants of Dakar peninsula, even though some people of other ethnic groups like Diola or Peul are now fishermen;
- Tourism for foreigners is particularly well

developed along the coast south of Dakar and in Casamance (about 126 km of coastlines) (Sene Diouf et al., 1993). Also an integrated rural tourism is developing, the infrastructures and management being under the responsibility of villagers. Thirdly, we must consider the "weekend" tourism for foreign residents and rich Senegalese people which consist in small villas built very close to the beach and only occupied during holidays. These touristic activities have determined a better infrastructure for these coastal zones in contrast with the interior. For coastal populations, they can be a source of income (employment, selling of seafood and agricultural products) as well as a cause of conflicts (expropriation of peasants). But whatever their inconvenience, they are a main source of foreign income (US$132 million in 1991);

- Agriculture: Together with various cultivations or cattle breeding which are practised in addition to fishing in small towns and villages. There are two main littoral agricultural activities:
  - market-gardening which is made in the "niayes" located in the greater Dakar and all along the coast between Saint Louis and Dakar. "Niayes" are interdune slacks where the water table reaches the surface. A lot of fruits and vegetables grow in these lows and cover most of the big towns demand, especially the greater Dakar area. In 1987, production was about 125,000 tons;
  - rice production is made in estuarine areas (Senegal, Saloum and Casamance) but is confronted with problems of aquifer and surface waters salinisation and soil acidification (sulfato-acid soils) which are one of the consequences of desertification and have destroyed large portions of mangrove leaving bare areas named "tannes" (Boivin et al., 1986; Diop, 1986).

Main Impacts of Climate Change in the Littoral Zone

The greenhouse induced warming of the atmosphere will determine a number of physical consequences which in turn will modify economic activities, settlement and global environment of coastal populations. These consequences have been broadly described in the first IPCC impact assessment (Tegart et al., 1990). For coastal zones, the main disturbing factor will be the acceleration of sea level rise which will induce a recrudescence of coastal erosion and inundation of low lying areas but also a reactivation of salt water intrusion in aquifers and surface waters. But it is important to also consider the possibility of upwelling modifications and other climate impacts of global warming which are till now out of reach for the global climate models (Mitchell et al., 1990).

The main conclusions of the study made on consequences for Senegal of a greenhouse induced acceleration of sea level rise are the following (Dennis et al., 1994) (Table 2):

- Land losses will be mainly due to inundation of estuarine areas, with destruction of all mangroves from a 1 metre sea level rise by the year 2100. Even if absolute land losses due to coastal erosion are low (2 to 5% of total land losses), the density of population and economic value of these lands are so high that they cannot be neglected;
- Depending on the scenarios, population at risk will represent 30,000 to 310,000 people or 0.9 to 4% of the 1990 population, but 4 to 19% of the coastal population; another not yet quantified consequence of sea level rise will be salt water intrusion in aquifers which is already a preoccupation along the Senegalese coastal zone (Gaye et al., 1989, Gaye and Faye, 1993).

Another impact of global warming that needs consideration is the possible modification of upwellings as a consequence of changes in atmospheric and oceanic circulation. Palaeoclimatic studies conducted in the Eastern Central Atlantic Ocean showed that during past climatic optimums, upwellings along West African coasts were reduced in intensity (Berger et al., 1978; Diester-Haass and Schrader, 1979) due to a weakening of the NE trade winds (Sarthein et al., 1981, 1982) or of the Canaries Current (Diester-Haass, 1980).

Table 2. Land, population and value at risk for different sea level rise scenarios by year 2100. (Dennis et al., 1994)

Sea level rise	0.2 m	0.5 m	l m	2 m
Land at risk (in km^2)	349–356	1678–1694	6042–6073	6494–6546
% land area	0.2	0.9	3.1	3.4
Population at risk (thousands)	30–50	69–104	112–183	193–310
% 1990 population	0.4–0.7	0.9–1.3	1.4–2.3	2.5–4.0
Value at risk (millions of US $)	142–228	345–464	499–707	752–1101
% 1990 GNP	4–6	9–11	12–17	19–27

Furthermore, a recent study of the impacts of climate warming on rainfed crops demonstrated that in the worst case (4°C rise in temperature and a 20% decrease in precipitation), three quarters of the arrondissements would be food deficit regions in 2050 (Downing, 1992).

Possible Impacts on Coastal Population

No global study about socio-economic impacts of climate change on coastal population is available. Nevertheless Fig. 2 is an attempt to identify main impacts on coastal populations considering three main factors: sea level rise, changes in upwellings and population growth. Four main consequences can be emphasised:

1. Food security will certainly be one major aspect of the impacts of global warming because we can predict:
   - A reduction in arable lands due to inundation and soil salinisation of lands especially in estuarine areas, destruction of the "niayes" due to salt water intrusion in the aquifers together with dune migration;
   - lower productivity of rainfed crops due to a diminution of precipitation;
   - reduction of fish resources due to a weakening of coastal upwellings and to the disparity of mangrove nursery grounds;
2. Water supply will become a problem due to salt water intrusion in aquifers and it will be worse in case of reduced precipitation. Considering the population growth rate and the rural migration, the water demand will not only considerably increase in big coastal towns but also all along the coast where wells will no longer provide fresh water;
3. Employment problems will increase if some important economic activities like fishing and tourism are adversely affected by climate change;
4. Resettlement problems will arise from the need to relocate populations threatened by inundation and shoreline retreat. Considerable pressure on land but also cultural and socio-economic problems not only for the displaced

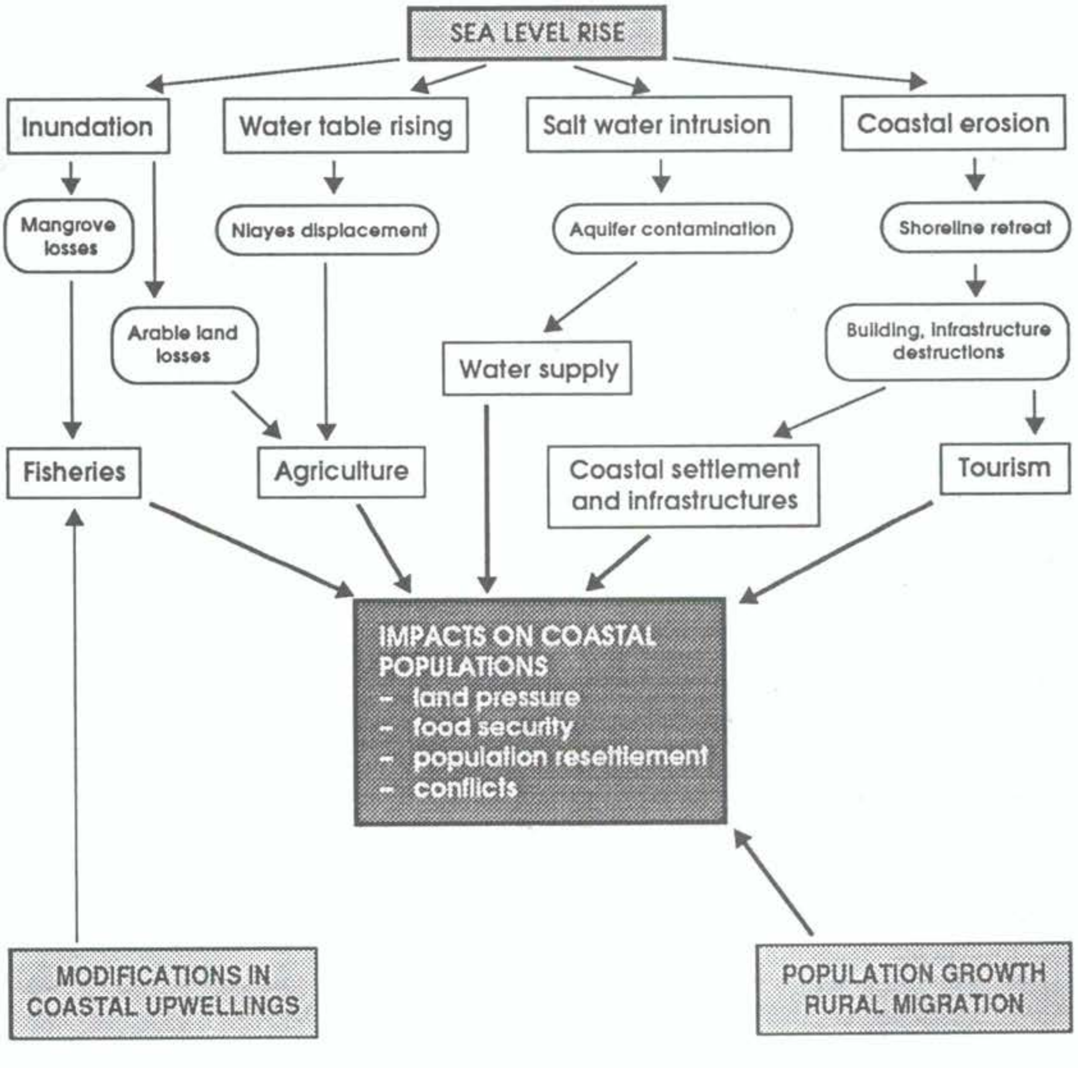

Fig. 2. Impacts of climate change on coastal populations.

populations but also for the receivers will arise. In a coastal environment already pressured, new social problems and conflicts will appear. Last but not least, we do not know how local ethnic populations will keep pace with these possible changes in their environment.

What To Do

If we are aware of all these possible evolutions of the coastal environment, our duty is to look for solutions. Following the IPCC recommendations for Integrated Coastal Zone Management Plans (ICZMP) (Intergovernmental Panel on Climate Change, 1992), we suggested the three following steps (cf. also Niang-Diop, 1994):

1. Analysis, with the following goals:
   - Make the inventory of the different factors (physical, human, socio-economic) interacting in the coastal zone. This work would permit us to understand the coastal environment and serve as a departure point for the establishment of a data base on the coastal zone;
   - Identify and rank the vulnerable areas using a set of criteria (scientific, economic, sociologic and so on);
   - Identify the gaps and uncertainties in our knowledge on climate change (particularly at a regional level) and try to reduce them;
   - Assess the responses of coastal zone to different scenarios of climate change implying not only changes in sea-level rise but also in precipitation, temperature, oceanic circulation and so on.

Few studies have focused on these subjects and need to be developed in order to afford a scientific basis for decisions.

2. Definition of a coastal zone management plan. The achievement of this step must involve two complementary sets of action:
   - Establish an institutional body, responsible for the decisions concerning a sustainable development of the coastal zone. This body must include different levels of interests: government representatives, private users and owners, non-governmental agencies, public associations, technical and scientific experts. But this institution must be able to make decisions and mechanisms must be found in order that it does not become another bureaucratic body. Also, this national body must have regional and local extensions or correspondents to assure feedback relations;
   - Determine priority uses and policies for each type of coastal zone identified on the basis of the ecological status, the needs for economic, recreational use and so on.

This step will require time due to the often conflictive interests in the coastal zone, the bureaucracy inertia and all the difficulties in establishing an operational institutional body.

3. Implementation. This other critical step will involve:
   - The creation of legal and financial tools permitting the achievement of the ICZMP;
   - The definition of a short and long term plan of implementation;
   - Creation of a network of regional and local structures in charge of the following up of the ICZMP in order to assure feedback mechanisms;
   - Develop public awareness about the importance of the ICZMP. Different levels of actions must be considered: audiovisual actions for the illiterate people; training of policy makers; development of an environmental education and involvement of youth in concrete actions in order to create new minds for the future;
   - Create a scientific network for the continuous monitoring of the coastal zone in all its aspects (physical, socio-economic, human...). This network must be correctly equipped and funded in order to assure a certain level of independency.

Two points need to be emphasised. First is the question of financial tools. In a developing country like Senegal characterised by a deficit in the current exchange balance, a low gross national product and an increasing external debt, the question of funding can simply prevent any development of an ICZMP. So it is necessary to look carefully at the sources of funding. Two main sources can be identified:

- At a national level, part of the budget must be allocated to an ICZMP but it will be necessary to complete this input by an "environmental tax". This tax will concern all the main users of the coastal zone with different degrees: For example, prohibitive taxes must be applied to the main pollutant factors located on the coastal zone, the tourism industry must also contribute but at a lower level. It is important that the success of such a policy depends on the political willingness. Indirect funding can result from the involvement of non-governmental agencies,
- At an international level, the contribution of the United Nations bodies will be solicited via for example the GEF. The World Bank must help countries involved in the implementation of ICZMP. Moreover, the external debt must be discussed in view of its reduction or suppression for countries applying the decisions of Agenda 21.

The second important question is that of training and technical assistance. If developing countries recognise the need in these domains, experience also indicates that priority must be given to exchange of experience and technical knowledge between countries of comparable level of development. So cooperation and exchanges must be developed at a regional level and with other developing countries.

To complete this reflection, it is necessary to understand that an ICZMP cannot be isolated from the rest of the national policies and problems. Considering what we know about the future demographic and economic evolution of the coastal zone, it is obvious that any ICZMP must be accompanied by the reinforcement or development of national policies in the following directions:

- reduction of the rural migration by developing economic poles in the hinterland, sustaining the agriculture and improve the conditions of living for the rural population. It is unrealistic to think that people will stay in zones where all aspects of life are a permanent challenge;
- management of water resources and perhaps development of seawater desalinisation units;
- development of renewable energies (in particular solar energy);
- continuous efforts for reforestation and replacement of charcoal and wood used for domestic purposes by alternative sources, perhaps via prohibitive taxes for those responsible for deforestation.

Moreover, we cannot forget the global economic context which in fact is not in favour of the full development of our developing (till when?) countries. So, the question of losers and winners is still open. Are developed countries really willing to help developing countries in their effort to fight against negative impacts of climate change? If yes, this implies to consider and modify the global economic context. If not, we will face in the near future more and more conflicts, endangering the efforts for peace and full human development. Time is up to consider all these issues if we do not want to transform the problem of global warming into a purely intellectual concept and debate.

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The Dilemma of Small Islands States and Other Coastal Areas in the Developing World

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Abstract—Positive progress on the further development of policy measures and instruments within the Framework Convention on Climate Change will depend on the political resolve to integrate equity as well as efficiency objectives into the Programme.

Small island states and low-lying coastal areas are becoming increasingly vulnerable to the negative impacts from the higher stormwater baseline that is occurring with sea-level rise. Concomitant with this phenomenon, extreme events are expected to become increasingly more important.

These countries already face a daunting challenge in attempting to establish priorities for the many social and economic problems they undergo and they certainly have not got the financial capacity to respond adequately to the threat of sea-level rise. In addition, such countries have made very small contributions to the global emissions.

Equity and social considerations will require a higher priority in the further evolution of the implementation of the Framework Convention on Climate Change.

It is a great honour for me to present this paper in front of such a distinguished audience. I feel that it is a very great responsibility too to convey to the international audience the dilemma of small islands states and that of the deltaic areas which in my opinion constitute, along with the desertification-threatened areas, those areas likely to be most vulnerable to global warming.

Overview

Those who signed the Framework Convention on Climate Change moved for the ultimate environmental goal within a context not only of economic efficiency, but also social equity, a clear priority being

> "to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". (Article 2 of the Framework Convention on Climate Change, United Nations, 1992).

The latter can only occur if certain standards of equity are respected, especially as regards those nations least able to help themselves and least responsible for the root source of the problem, itself an economic development process which has widened considerably the developmental gap between the developed and the developing world.

Those standards are well spelt out in the Convention, which acknowledges that:

> "the largest share of historical and current global emissions of greenhouse gases originated in developed countries",

and calls for the widest possible cooperation, precautionary principles, intergenerational fairness as well as cost effectiveness, without any disguised restriction on international trade and within a context of differentiated responsibilities with developed countries taking the lead.

Furthermore, Principle 3 spells out that:

> "where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost".

The inadequacy of the response to date to the social equity objectives spelled out, two years back, speaks eloquently of the need to reactivate the debate. I shall illustrate my point from the example of the small island developing states and the low-lying developing deltaic states.

Our Subject Areas

The small islands states of the world comprise over 70 states of vibrant communities of various cultural origin that operate at varying levels of economic performance. By reason of their size and their activities, their entire geographical areas are considered as coastal zones.

Being heavily oriented towards the coast, they are not only vulnerable in physical terms, but also in terms of socio-economic activity. At the same time, in view of their relatively small economies, costs of adaptation would be prohibitive.

The low-lying nature of deltaic areas such as Bangladesh or the Nile Delta renders them particularly vulnerable to sea-level rise. These areas are among some of the most densely populated areas of the world.

The vulnerability of both categories of areas to sea-level rise is not contested. Both categories are already encountering many problems arising from the unsustainable use and unrestricted development of coastal areas and resources, itself often the result of population pressure, poverty, survival and ignorance. Both areas already undergo from time to time the onslaught of significant causes by climate variability such as cyclones and monsoons, all these being independent of the climate change issue, but which the latter could exacerbate.

Climate Change and The Coast

The Conference Report of the World Coast Conference (IPCC, Preparing to Meet the Coastal Challenges of the 21st Century, April 1994) states the following in respect of climate change and the coast:

> "Climate change and climate variability are likely to aggravate the impacts of unsustainable development of coastal areas and resources. In turn, these impacts will further exacerbate the vulnerability of coastal areas to the consequences of climate change and associated sea level rise".

In its First Assessment Report, the IPCC Report predicted a global mean sea level rise of 3–10 cm per decade. This rise is more than 3 times faster than that experienced over the last 100 years. Even with actions to limit emissions, some rise in sea level is still predicted, due to some lags in the overall system.

The IPCC 1992 Supplement did not revise the 1990 Report's estimate of sea-level rise.

It is a fact that those who are searching for the sea-level rise issue find that more impact assessment reports highlight the warming issue and not the sea-level rise issue. The sea-level rise issue tags on as an additionality.

However, for small islands and low-lying coastal areas, sea-level rise constitutes an irreversible threat in view of the existing relativity of the areas of activity and infrastructure to existing sea-level.

Whilst there is scientific uncertainty regarding the timing and regional impact of global warming and numerous scenarios are being worked out to determine who would be the likely winners and losers, there is no doubt about the specificity and vulnerability of small ocean islands and coastal areas lying largely just a few metres above sea-level. They would all be losers.

> "A rise in sea level would (i) inundate and displace wetlands and lowlands, (ii) erode shorelines, (iii) exacerbate coastal storm flooding, (iv) increase the salinity of estuaries and threaten freshwater aquifers and otherwise impair water quality, (v) alter tidal ranges in rivers and bays, (vi) alter sediment deposition patterns, and (vii) decrease the amount of light reaching ocean bottoms". (p. 6–1 IPCC Impacts Assessment Report, 1990).

Such areas are furthermore currently exacerbated by population growth, competition for resources, including freshwater, land and human capability resources, degradation of the environment, problems of governance, food security, health care as well as mitigation of disasters often caused by unfavourable weather conditions and made more difficult on account of poor infrastructure.

Taking into consideration on the one hand the vulnerability, smallness and weakness of the economies involved and the lack of involvement in the cumulation of processes which have led the world to this quasi-irreversible situation, and, on the other hand, the disproportionate burden of the potential impacts of global warming on these areas, it is obvious that there are strong equity considerations that arise in the management of information, let alone the sharing of responsibilities over this new phenomenon affecting the world.

We shall go a bit deeper into the predicament of small islands and other coastal areas in the next section.

Predicament of Small Islands States and Other Vulnerable Coastal Areas

The needs and aspirations of human beings in small island states, and other vulnerable developing coastal areas—including responsibilities to future generations—are no different from those of the larger developed countries. They all aspire to food security, a home that would provide shelter from vagaries of the weather and other importunities, job satisfaction, a higher level of economic development, leisure as well as a sustainable future for their offspring.

Specificities

The specificities of these areas are such that the problems being faced in the pursuit of sustainable development are already complex and are being increasingly compounded under the prospects of climate change and sea-level rise.

So far as our islands are concerned, smallness of size is also magnified by the fact that many of the island states are not made up of single islands, but of several small islands, sometimes a considerable distance apart.

The islands are generally characterised by a narrow resource base, excessive dependence towards international trade and hence excessive vulnerability in respect of external markets; distance to market problems, including high costs of freight; population density which increases pressure upon land for housing and other productive activities.

The scope for productive activities on islands is limited and is predominantly monoculture, alongside traditional fishing and some tourism. The biggest assets of those islands are their large EEZ areas which the Law of the Sea has conferred upon them, but it is noted that most of these countries lack the capacity of surveillance for these areas which are in practice being exploited by the larger nations.

Multiple use of resources upon small islands impinges upon limited land as well as water resources and creates serious competition between different land-use options, including those areas which need to be protected such as catchment areas, wetlands and other coastal ecosystems, parks and forested areas. This threatens biodiversity. By reason of their isolation, small islands are characterised by a high degree of endemism and species get rapidly threatened.

The low-lying nature of deltas make them particularly vulnerable to sea-level rise. The sheer problem of deltas relates to their size, the large numbers of population that dwell on them and the galloping rate of increase that is occurring now. Bangladesh is an example of a country where, when river floods occur, this can affect 65% of the country at one time (IPCC Response Strategy Working Group 1992: Global Climate Change and the Rising Challenge of the Sea). In late 1970, storm surges killed approximately 300,000 people in Bangladesh and reached over 150 kilometres inland.

Natural flooding and the resulting sedimentation can enable deltas to keep pace with sea level rise. However, the construction of dams and other flood-prevention structures, without proper EIAs in the past, reduced sedimentation in deltas, accelerating erosion and subsidence.

Primary Impacts

The primary impacts of sea-level rise would, in either of those areas, be on physical property and the economic activities and ecological systems astride the coast. Sea level rise would result in increased loss of valuable coastal land, damage property, cause increased flood related deaths, affect coastal ecosystems and also eventually lead to loss of territorial seas.

Research also suggests that extreme events may become more frequent as a result of increased ocean temperatures which would change the frequency, duration and intensity of tropical storms. Inundation of coastal areas is already common during tropical storms and any increases in the extent or frequency of inundation may render numerous heavily populated areas marginal or uninhabitable.

Sea-level rise would increase the severity of storm related flooding and the higher base for storm surges would be an important additional threat in areas where hurricanes and tropical storms are frequent.

Secondary Impacts

Beyond the primary impacts of climate, secondary effects would occur, some of which would be even more complex than the primary ones. A very sensitive impact would be on the hydrological resources, where the low coral islands have almost absolute dependence on underground water, found in the freshwater depths below.

With the current problems of overpopulation and multiple use of resources, freshwater resources are already available below sustainable limits. Changed temperature and rainfall patterns as well as higher evapotranspiration would reduce the amount available for recharge, resulting in even more marginal conditions for sustainable development.

Agriculture would be another of these areas of complex impact. The 1990 IPCC Impacts Report had the following to state in respect of sugarcane:

> "A probable area of impact in the tropics will be on sugar production, reducing further the value of the sugarcane crop in tropical countries relative to the success of sugar beet (C3) in the temperate zone..."

More carbon dioxide, higher temperatures, the seasonal distribution of rainfall, extremes such as droughts or storms would affect development factors whilst indirect effects would occur through reduced land availability and hydrological resources. Such factors would shift spatial patterns in the long run and affect competitiveness.

The subject areas we are dealing with are also no different from their Northern counterparts in that there is major infrastructure along the coastal areas in the form of ports, urban development, coastal roads, tourist resorts. Such infrastructure is, however, of much lower specification than their Northern counterpart and is also badly maintained. They will be increasingly under risk, requiring increased rehabilitation costs after every storm.

The capacity of small islands and their economies to absorb the impacts of irreversible events is much smaller than in the case of larger areas.

Neither have low-lying developing states like Bangladesh got the capacity to adapt to sea-level rise.

The practical and cost considerations are as follows:

> A dilemma facing Majuro Atoll in the Marshall Islands is determining the source of the necessary materials for raising the land surface (The Rising Challenge of the Sea, IPCC, 1992, p. 16). The next problem is costs: Protection in Majuro against a 0.3 m rise in sea-level would cost 1.5 to 3.0 times the present GDP.

The total estimated costs for protecting the Maldives is set at US$ 1 billion. Maldives has already started evacuating residents from four islands because the resources for protecting all the islands are not there, and, taking into consideration the likelihood of impending threat, proactive measures should be considered as of now, but the incremental costs of many adaptive measures are beyond the capacity of most of the developing nations—as is starkly evident in the other additional burdens falling upon these nations.

In the light of the above, the added prospects of loss of land and greater vulnerability through climate change and sea level rise are of very grave concern to the small islands and other low-lying areas already constrained by limited development perspectives.

The above review brings us to the further consideration of equity issues:

Equity and Social Considerations

Abnormality of the Burden

The review of the vulnerability of small islands and coastal states as spelled out in the foregoing sections bring out the disproportionate and abnormal burden (including quasi-annihilation in the case of the atoll islands) that such areas would undergo as part of the impact of climate change and sea-level rise. The prospects are likely to be irreversible. I have not found anything contradicting this in the scientific reports.

No Capacity for Resilience

Countries with larger surface areas and higher elevations can offer higher prospects of resilience and adaptation. In small ocean islands, the degradation of water supplies through saltwater intrusion can alone dictate the end of any sustainable prospects for present, let alone future generations. Large deltaic areas in developing regions have a different limitation for resilience. Their economic resilience is weak and impacts, when they occur, are wide-ranging.

Problems of Capability

There is also the question of differentiated physical capability to deal with the problem. In view of the dimensional aspect of the problem, retreat is quasi-impossible in our subject areas, and provided aquifer supplies remain sustainable, the question of adaptation may be evoked. But the costs implications of such options, the scope of which has been given earlier, would be beyond the reach of most of the countries involved.

Limited Responsibility for Build-Up of Greenhouse Gases

The small ocean islands and the developing coastal states have had little to do with the processes that are causing an accelerated warming of the atmosphere. Their consumption patterns, since times immemorial, have been modest, often on survival lines, and have nothing to compare with the consumption patterns of the North.

Dominance of Developed Country Research

The research and the examples in the IPCC Working Reports are dominated by the scientists of the developed economies who command an articulate voice at international forums. Active participation kindles interest and brings together policy makers and scientists, a process which, in the environmental field, is normally absent among the small nations where politicians are more concerned with the problems of governance, survival, job creation, food security and so forth.

Symbolic Representation of Developing Countries

There is a commitment to the participation of the developing countries in the IPCC process, but this participation has been, is and will remain largely symbolic. The developing country research capability, especially that of the small island countries is extremely limited.

Management of Information

Whilst large sums have been committed towards global warming research by the developed countries—the powerful environmental lobby facilitates the release of substantial funds for massive research programmes on global change, but does not necessarily guarantee that money will be pumped into endangered areas outside their national boundaries—a full international process has merged towards the submission of voluminous reports as part of the First IPCC process. It is inequitous that the special problem of these areas is not specifically highlighted in most reports.

The strong economies have commanded the most articulate voice in the previous IPCC process and they obviously still do in the current process, the developing countries, especially the island nation ones being confronted by problems of capacity building of their own.

Island issues have been generally brushed aside in the IPCC Working Papers. Were it not for the immediacy of the problems of the atoll islands, in respect of which the Maldives and the South Pacific islands have taken the initiative to mobilise international interest, perhaps there would have been no coverage of islands at all, except for some passing references to Fiji, well documented upon by Nunn, (1989).

Is there a trend towards Management of Information? A carefully worded Report intended for the US Congress in March 1990 promoted the idea that,

> "Whilst there is general agreement among scientists on the current state of understanding of climate processes and on the degree of reliability of current models for projecting climate change, there is less agreement on whether current information, with its uncertainties, can and ought to be used as a basis for policy". (Morrison R., CRS Report for Congress—Global Change and the Greenhouse Effect: Prediction and Uncertainties, March 1990).

It is noted that whilst the Report spells out

> "confidence in the direction of sea-level rise as well as the generally greater risks for poor countries, which largely depend on natural ecosystems and lack resources to insulate themselves from climatic shifts, than for wealthy nations",

there is no mention in the Report of the problems of survival of either small island nations or deltaic states and the differential impacts that the global change poses. Is this a careful omission ?

Inequities in Costing Climate Change

Numerous attempts have been made in the recent past to quantify the impacts of climate change as a basis for calculating optimal policy responses and some such attempts suggest that the costs may be rather modest and insufficient to justify such abatement effort at present.

Michael Grubb ("The Costs of Climate Change: Critical Elements", Paper to the IIASA Conference on the Impacts, Costs, and Possible Benefits of Measures to Limit Climate Change, IIASA, Laxenberg, October 1992) has rightly pointed out that such estimates suffer from important limitations because they do not *inter alia* make valid extrapolations from industrialised to developed countries and ignore the possibility of major and costly surprises arising from the sheer complexity of the system.

Most studies estimate the costs of climate change as one percent of GDP, but this figure was extrapolated from studies based on the robust economy of the US, where much of the economy is not vulnerable to climate change.

The figures also assume a smooth transition to a state with double CO_2 concentrations, as estimated by mid-range equilibrium GCM modelling studies, but it is unlikely that, for the small island states and the deltaic areas like Bangladesh, the transition will be that smooth. Extreme events like flooding or drought, taking into consideration the flooding trends of Bangladesh and the drying trends of Africa, that have already claimed millions of lives, are more probable with considerable human and financial costs.

The cost to the Mauritian economy, which is relatively robust compared to other small island states, of Cyclone Hollanda which struck the island in early 1994 is estimated to have amounted to approximately 3% of GDP. On account of vulnerable infrastructure (such as overhead electric cables), each extreme event is potentially capable of significant disruption.

For low atoll islands dependent on aquiferous hydrological resources, the onslaught of storm surges would annihilate the long term possibility of continued sustainable living—the loss of a complete cultural identity—what market valuations can be placed on the same?

Additional case studies of vulnerable areas have been initiated this year as part of World Coast Conference 1993 and profiles for selected areas at risk are published in the Conference Report which was published in April 1994.

Following examination of the profile for Mauritius, with which the author is familiar and which the author believes is underestimated, it is felt that more complete studies, with very rigorous indicators for global comparison need to be undertaken.

However, the Global Vulnerability Analysis does state that because of regional differences in regimes of storm surge events, the risk of flooding risk due to sea-level rise is greater than average for some areas including the coast of the Carribean and other small island states. It is also confirmed that the global costs for basic protection works would constitute a substantial part of GNP for Indian Ocean and Pacific Islands.

Policy Instruments: Their Pace

The unquestioned commitment of the industrialised countries to ecological security is being seriously compromised by the slow pace with which they are introducing limitation measures on greenhouse gases. This speaks of little or no concern for the vulnerability of the small innocent and fragile nations which have been at the receiving end of actions that have "exhausted" the Global Commons. The prolonged delay itself is also an open flouting of the precautionary principle which the Convention advocates.

Inter-Generational Issues

The bulk of world population, as projected in the future, would occur in the developing world. Agenda 21, Chapter 17, suggests that up to three-quarters of the world's population could be living within 60 km of the shoreline by the year 2020. World Bank experts suggest that two-thirds of the population of developing countries (3.7 billion) is expected to be living along the coast by the end of this century.

It is evident that the equity and social issues raised here would relate not only to the present populations, but also to the unborn generations of the areas we are discussing.

Issues and Recommendations

A highlight of the major issues and recommendations which emanate from this review would be as follows:

Low Priority on the Agenda

Whilst small island nations and low-lying deltaic states in the developing world have more to lose from climate change than most of the rest of the world, such issues are clouded by other problems of immediate survival, such as poverty, hunger, governance, disease as well as economic development. Moreover, they are not in a position to finance adaptation measures. The specific dilemma of these vulnerable areas and the financing of response strategies do not seem to feature as a high priority on the Agenda for implementation.

Scope for Redress

Action to mitigate the impacts on the areas of my talk would comprise measures to reduce the concentration of GHG emissions on the one hand and on the other hand, financial resources to provide adaptive measures.

The Menu of Instruments

A host of policy instruments, economic, regulatory as well as other programmes, are being debated, with respect to their feasibility and cost effectiveness. Numerous complex issues are arising, such as free riding, leakages, tax incidence, timespan. It is important that the debates be not overstretched beyond the intention of the original policy, i.e., to reduce emissions in the most cost efficient and equitable manner.

The question of who should pay for reducing emissions is a separate one from questions of *what type of reductions are most urgent* and *where they can be readily and most inexpensively implemented.* Most cost-effective measures to reduce greenhouse gas emissions will be in developing countries, in part, because income constraints have often resulted in relatively inefficient processes being used (Ali M. Azimi, Proceedings of the Tsukuba Workshop of IPCC WG III, Jan. 1994, p. 319).

Need for International Cooperation

There is no escaping from the conclusion that if the world is to reduce greenhouse gas emissions, developing countries must all be active participants in the process and to that end, a climate of solidarity based on social and economic considerations as well as differentiated responsibility for priority action, with developed countries taking the active lead, with concrete initiatives.

Developing countries need to be won to that cause. Although they also stand to be losers if they do not comply, they perceive, and rightly so, their immediate survival problems to be their immediate priority and that the GHG problem has to be resolved by the nations that were responsible for it.

Resource Transfers

Action by developing countries will require transfer of technology and financial resources from developed countries as provided for by the Framework Convention.

Any evaluation of such action will need to consider the evolution of energy policy and planning in the developing countries. Any energy transition and major efficiency measure will require major resource transfers to deflect existing policy paths towards more environmentally acceptable options.

Emphasis on Precautionary Policies

A climate of solidarity will pave the way for the bringing in of precautionary policy measures like energy conservation. Energy pricing may eventually play an important role in containing and reducing the problem.

> "Recent World Bank studies show that getting energy prices right makes good economic as well as environmental sense". (B. Larsen and A. Shah, Proceedings of the Tsukuba Workshop of IPCC WG III, p. 34)

Avoidance of Environmental Colonialism

It is also important that any resource transfers effected in connection with Joint Implementation measures are not accompanied by a novel attitude of environmental colonialism.

Avoidance of Distortion of Existing Aid Arrangements

The transfers associated with Joint Implementation in developing countries should not displace existing aid arrangements which, in the normal order of things, are helping to shape social and economic policies and move countries out of the survival stage. They should be seen clearly as an additionality, arising,

> "from the mutual desire on the part of two equal partners to come to some agreement". (T. Jones, OECD, Proceedings of the Tsukuba Workshop of IPCC WG III, p. 212)

and without any sense of gift. In the same above-mentioned paper, Jones also speaks of the risks of cream-skimming by the developed country partner, who would "pick off" the cheapest abatement option, leaving the developing countries to pay a higher price later on when they begin to abate themselves.

Emphasis on Energy Efficient Technologies

It is essential that the significant development paths of the developing countries be steered towards more sustainable practices than presently possible with inefficient technology.

The developing countries should be given the opportunity to leapfrog into more energy efficient technologies, as a fundamental ingredient in the process of economic development (Goldemberg, Jose in *The Regions and Global Warming*, edited by Schmandt and Clarkson, 1992, Oxford University Press, 235 pp.).

If this is properly conducted, the growth and further development of the developing countries will become less of a threat to the future stabilisation of the atmospheric composition. The technical and financial resources must come from the developed countries.

Conclusions

International cooperation to address climate change in a fair, equitable and cost-effective manner is essential. We live today in a threatened world.

The increased concentration of greenhouse gases in the atmosphere is the legacy of the industrialised nations, in their quest for aggressive industrial development.

Certain areas, like small island states and other low-lying areas are coming under immediate threat, but the issues of such areas do not feature as a priority on the Agenda.

There should be greater commitment to remedial action from the industrialised countries, in keeping with the wording as well as spirit of the Framework Convention on Climate Change, in terms of both financial and technology transfers.

Disclaimer: Please note that views and opinions expressed are personal and do not commit the Mauritius Government for whom the author works.

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Discussant's Comments

Social and Cultural Aspects of Climate Change

R. S. ODINGO*

I have a very strong feeling that throughout this workshop and even in much of the work of IPCC's other Working Groups, we have been too obsessed with climate change which we can only surmise, rather than with climate variations which many of us have obviously experienced. The truth of the matter is that for most of us we are bound in our lifetime to experience and even suffer from the consequences of climate variation even if we do not sample a true climate change. The fact is that our obsessions with climate change derive more from our reading about, and for those of us who live in areas which are subject to climate extremes, we have been forced to sample climate variations with their attendant consequences such as:

(i) Drought
(ii) Famines
(iii) Food shortages
(iv) Widespread livestock mortality
(v) Population displacement.

The experiences in Africa over the last 20–25 years underline the significance of climate variations even more than climate change. Professor Bolin in some of his interventions during this session of the Workshop has endeavoured to remind us to realise the importance of this aspect of climate change which we understand much better than those areas which we can model but which we only understand partially.

From the biophysical point of view we now understand very well some of the linkages of, for example:

(a) El Niño—Southern Oscillation (ENSO) Events—and the accompanying, often prolonged weather disturbances, which can go on for up to five years at a time.
(b) Bad droughts which many regions in Africa, such as the Sahel have experienced over the last 20–25 years.

Prof. Yuri Izrael took the opportunity during his presentation to highlight the social consequences of drought in some of the republics of the former Soviet Union, and to link these with future climate change and what might be expected. The link between drought and desertification is clearly worrying, not least because of the social ramifications to the affected populations. Professor Kenneth Hare in his effort to enlighten many similar discussions sought to distinguish between a short-lived drought and a **dessication**, i.e., a drought which may last up to 20 years. It is only when we see climate variations in these more extended terms that we can begin to appreciate the untold socio-economic impacts that are experienced, and this helps to give us a foretaste of what may be expected in the event of climate change under conditions of global warming.

The Aral Sea experience highlighted by Professor Izrael is quite interesting. He indicated that this lake is known to be drying out, or has even dried out largely due to human interference and from this I could understand why he was interested in making comparisons with Lake Chad in Africa in an earlier paper presented by another speaker. The link between anthropogenic impacts in combination with natural processes helps us to understand concepts such as "desertification". Natural processes of climate variations exacerbated by human impacts leads to disruption of pastoral societies, salt in the atmosphere, destruction of agriculture and high mortality among the affected populations.

The paper by Dr Mohamed Suliman on conflict in the Sudan, linked to drought occurrence and even the possibility of climate change was very illuminating. He emphasised the link in several areas of the Sudan with ecological imbalance, prolonged droughts (cf. dessication) and social conflicts ending up in actual wars between various groups in the Sudan. This from the socio-economic point of view was very interesting because it indicated the kind of social frictions which may accompany climate change in the future.

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Dr Sidibe emphasised the impact of climate variations on nomadic populations in Mali. His presentation also underlined the need to think of "dessication" (cf. 20 years drought) rather than the short-lived individual droughts. The experiences of the Sahel in the last 20 years may indeed be a dress rehearsal of what may be expected in a globally-warmed world—at least on a regional level. The social consequences of such dessications speak for themselves and the equity implications are readable in all the reactions to these changes. The social conflicts emanating from compétition for resources are instructive. In 1988, the Royal Swedish Academy of Sciences held a workshop in Stockholm focusing on these very issues under the title "Environmental Security". This put an emphasis on both drought and even climate change and the social conflicts which they generate and this provides a useful link with the discussions held the previous day which was focusing on "Environmental Refugees". The decrease in ecological resources during droughts is globally driven. Societal responses are a dynamic process with equity implications.

Equity Within Countries

Chair : Karl-Göran Mäler and
Richard Samson Odingo

Rapporteur: J. Kinuthia

Potential Impact of Climate Change on World Food Supply*

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Abstract—A global assessment of the potential impact of climate change on world food supply suggests that the doubling of the atmospheric carbon dioxide concentration will lead to only a small decrease in global crop production. But developing countries are likely to bear the brunt of the problem, and simulations of the effect of adaptive measures by farmers imply that these will do little to reduce the disparity between developed and developing countries.

Recent research assessing the potential effects of climate change on agriculture has focused on regional and national evaluations.[1–3] These efforts have, for the most part, treated each region or nation in isolation, without relation to changes in agricultural production elsewhere. Recent work[4–5] emphasises the important role of international trade in the adjustment of the world food system to climate change-induced changes in crop yields. Crop growth models have been used in an extensive international collaboration[6] to determine the effect of various climate change scenarios on crop yields for individual countries and geographical regions (Fig. 1). In this article we combine the data from these individual studies to obtain a global picture of the simulated change in crop yield associated with different climate change scenarios. We then use a world food trade model to simulate the economic consequences of these potential changes in crop yields; we estimate changes in world food prices, and in the number of people at risk of hunger (defined as a measure of food energy availability—which depends on income and food price levels—relative to nutritional requirements) in developing countries.

The major finding of the study is that there appears to be a large disparity in agricultural vulnerability to climate change between developed and developing countries. This occurs even though simulated global agricultural production of major grain crop declines are only small to moderate under the climate change conditions tested. The analysis included the combined effects of climate change and

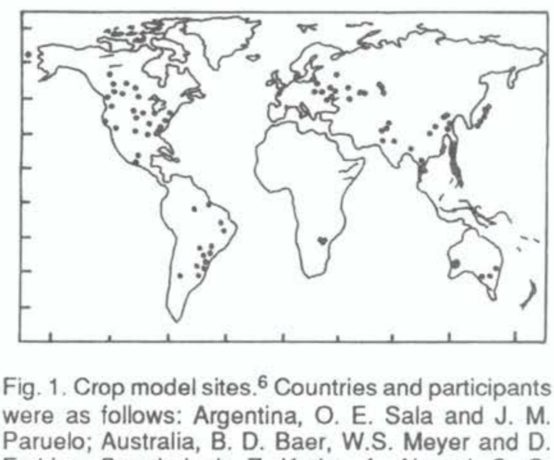

Fig. 1. Crop model sites.[6] Countries and participants were as follows: Argentina, O. E. Sala and J. M. Paruelo; Australia, B. D. Baer, W.S. Meyer and D. Erskine; Bangladesh, Z. Karim, A. Ahmed, S. G. Hussain and Kh. B. Rashid; Brazil, O. J. F. de Siqueira, J. R. B. Farais and L. M. A. Sans; Canada, M. Brklacich, R. Stewart, V. Kirkwood and R. Muma; China, Z. Jin, D. Ge, H. Chen, J. Fang and X. Zheng; Egypt, H. M. Eid; France, R. Delécolle, D. Ripoche, F. Ruget and G. Gosse; India, D. G. Rao; Japan, H. Seino; Mexico, D. Liverman, M. Dilley, K. O'Brien and L. Menchaca; Pakistan, A. Qureshi and A. Iglesias; Philippines, C. R. Escaño and L. Buendia; Thailand, M. L. C. Tongyai; Russia, G. Menzhulin, L. Koval and A. Badenko; USA, C. Rosenzweig, B. Curry, T. -Y. Chou, J. Ritchie, J. Jones and R. Peart; Uruguay, W. E. Baethgen; Zimbabwe, P. Muchena.

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1 Parry M. L., Carter T. R. and Konijn N. T. (Eds.) *The Impact of Climatic Variations on Agriculture*. Vols I and II ((Kluwer, Dordrecht 1988).

2 Adams R. M. et al. *Nature* 345: 219–224 (1990).

3 Intergovernmental Panel on Climate Change. *Climate Change: The IPCC Impacts Assessment* (Edited by Tegart W. J. McG., Sheldon G. W. and Griffiths D. C.) (Aust. Govt Publishing Serv., Canberra, 1990).

4 Kane S., Reilly J. and Tobey J. Report AER-No. 647 (US Dept of Agric. Econ. Res. Serv., Washington DC, 1991).

5 Reilly J. and Hohmann N. *Am. econ. Ass. Pap. Proc.* 83: 306–312 (1993).

6 Rosenzweig C. and Iglesias A. (Eds.) *Implications of Climate Change for International Agriculture: Crop Modelling Study* (US Environmental Protection Agency, Washington DC, in press).

increasing CO_2 on crop yields and water use. Although projected temperature change in low latitudes (where many developing countries are located) tends to be lower than the global average in the general circulation model (GCM) scenarios tested, modelled yield changes are primarily negative there, in contrast to predominantly positive yield changes in middle and high latitudes where many developed countries are located. This result has significant implications for potential future distributional aspects of the world food system.

Studies such as this explore the sensitivity of important human systems (in this case world food supply), as currently understood, to projected levels of global climate change. Such studies are initial demonstrations of the comprehensive, interdisciplinary research needed to improve understanding of the interactive biophysical and socio-economic effects that may result from global environmental change.

Climate Change Scenarios

Scenarios were developed from climate conditions predicted by three GCMs for doubled atmospheric CO_2 levels (Table 1). The temperature changes of these GCM scenarios (4.0–5.2°C) are near the upper end of the range (1.5–4.5°C) projected for doubled CO_2 warming by the IPCC.[7,8] Mean monthly changes in temperature, precipitation and solar radiation from the appropriate GCM gridbox were applied to observed daily climate records (1951–80, or as many years of daily climate records as available) to create climate change scenarios for each study site.

Because atmospheric concentrations of other greenhouse gases besides CO_2 (for example, methane (CH_4), nitrous oxide (N_2O) and the chlorofluorocarbons (CFCs)) are also increasing, an "effective CO_2 doubling" has been defined as the combined radiative forcing of all greenhouse gases having the same forcing as doubled CO_2, usually taken to be ~600 ppm. CO_2 level is important when estimating potential impact on crops because crop growth and water use have been shown to benefit from increased levels of CO_2.[9,10] For the crop model simulations, climate changes from the doubled CO_2 GCM simulations were used with an associated level of 555 ppm CO_2; these conditions are assumed to occur in AD2060. The 555 ppm level is based on the GISS GCM trace gas scenario A,[11] in which the simulated climate had warmed to the effective doubled CO_2 level of ~4°C by AD2060.

Crop Yield Change Methods

Agricultural scientists in 18 countries estimated potential change in national grain crop yields using comparable crop models and the GCM scenarios at 112 sites (Fig. 2). The crop model linkages were developed by the US Agency for International Development.[12] Simulations were carried out in regions representing 70–75% of the current world production of wheat, maize and soybean; rice production was less well represented (48% of current world production).

Site-specific estimates of yield changes were aggregated to national levels based on current

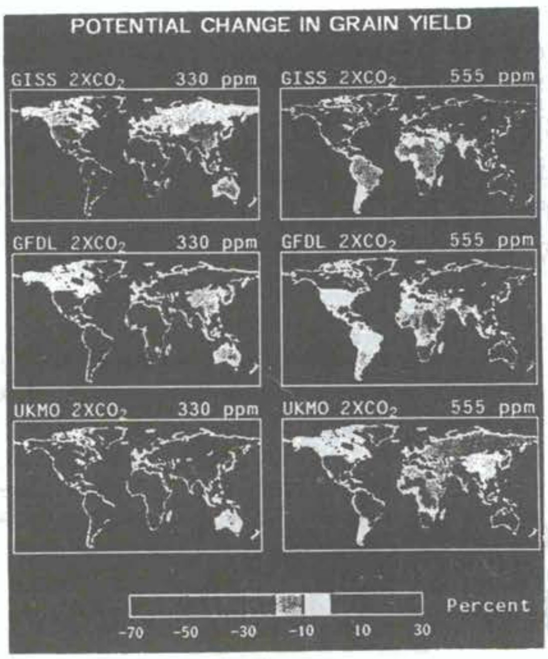

Fig. 2. Estimated change in average national grain yield (wheat, rice, coarse grains, and protein feed) for the GISS, GFDL, and UKMO climate change scenarios. The left-hand column shows the direct physiological effect on grain yield of current (330 ppm) CO_2) concentration. The right-hand column shows the direct physiological effect of 555 ppm. Results shown are averages for countries and groups of countries in the Basic Linked System (BLS) world food trade model; regional variations within countries are not reflected.

[7] *Climate Change: The IPCC Scientific Assessment* (Edited by Houghton J. T., Jenkins G. J. and Ephraums J. J.) (Cambridge Univ. Press, 1990).

[8] IPCC *Climate Change 1992* (Edited by Houghton J. T., Callander B. A. and Varney S. K.) (Cambridge Univ. Press, 1992).

[9] Acock B. and Allen L. H. Jr in *Direct Effects of Increasing Carbon Dioxide on Vegetation* (Edited by Strain B. R. and Cure J. D.) pp. 33–97 (US Dept of Energy DOE/ER 0238, Washington DC, 1985).

[10] Cure J. D. and Acock B. *Agric. For. Met.* 38: 127–145 (1986).

[11] Hansen J. *J. geophys. Res.* 92: 9341–9364 (1988).

[12] International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) *Decision Support System for Agrotechnology Transfer Version 2.1 (DSSAT V2.1)* (Dept Agron. and Soil Sci., Coll. Trop. Agric. and Hum. Resources, Univ. Hawaii, Honolulu, 1989).

regional production. The regional yield estimates represent the current mix of rainfed and irrigated production, and today's crop varieties, nitrogen management and agricultural soils. The national crop yield changes were then extrapolated to provide estimates of yield changes for the other countries and crops included in the world food trade model. National yield changes of other crops and commodity groups and regions not simulated were estimated based on three criteria: (1) similarities to modelled crops and growing conditions; (2) results from ~50 previously published and unpublished regional climate change impact studies; and (3) projected temperature and precipitation changes from the GCM scenarios. The primary sources of uncertainty in the estimates lies in the sparseness of the crop modelling sites and the lack of explicitly modelled yield changes for subsistence crops such as millet and cassava, which may respond differently to both climate change and increases in CO_2.

Estimates were made of yield changes with and without the direct physiological effects of CO_2 on crop growth, that is increased rates of net photosynthesis and reduced stomatal openings as reported from experimental results.[13] The photosynthesis ratios (555/330 ppm CO_2) for soybean, wheat and rice, and their size were 1.21, 1.17, and 1.06, respectively. Changes in stomatal resistance were based on experimental results[14] (49.7/34.4 s m^{-1} for C3 crops, 87.4/55.8 s m^{-1} for C4 crops). This method of simulating the physiological CO_2 effects on crops may provide a positive bias to yield estimates, as plants grown in experimental settings are often subject to fewer environmental and competitive stresses than are likely to be encountered in farmers' fields.

GCM Scenarios and Direct CO_2 Effects

Figure 2 shows estimated potential changes in average national grain crop yields for the GISS GFDL and UKMO doubled-CO_2 climate change scenarios (Table 1) with and without physiological (direct) CO_2 effects on plant growth. The maps are created from nationally averaged yield changes for wheat, rice, coarse grains and protein feed estimated for each country or group of countries. When climate change is considered without direct CO_2 effects on crop growth and water use, averaged national crop yields declined everywhere, although reductions were less at middle and high latitudes. In the simulations with direct CO_2 effects, yields were positive at middle and high latitudes, and negative at low latitudes for the GISS and GFDL scenarios which produced yield changes ranging from +30 to -30%. The UKMO scenario caused average national crop yields to decline almost everywhere (up to -50% in Pakistan).

Several factors contributed to the latitudinal differences in simulated yields. At some sites near the high-latitude boundaries of current agricultural production, increased temperatures benefited crops otherwise limited by cold temperatures and short growing seasons. In many middle and high latitude areas, where current temperature regimes tend to be cooler, increased temperatures exerted a negative influence on yields through shortening of crop development stages, but did not significantly increase heat or water stress levels. In these regions beneficial CO_2 effects dominated. The climate-change-induced warming at low latitudes brought not only accelerated growing periods for crops, but also greater heat and water stress, resulting in greater yield decreases than at higher latitudes, despite beneficial CO_2 direct effects.

Table 1. GCM doubled-CO_2 climate change scenarios

GCM	Year*	Resolution (lat. x long.)	CO_2 (ppm)	Change in average global temp. (°C)	Change in average global precipitation (%)
GISS+	1982	7.83° x 10°	630	4.2	11
GFDL‡	1988	4.4° x 7.5°	600	4.0	8
UKMO§	1986	5.0° x 7.5°	640	5.2	15

*When calculated.
+Goddard Institute for Space Studies.[15]
‡Geophysical Fluid Dynamics Laboratory.[16]
§United Kingdom Meteorological Office.[17]

[13]Peart R. M., Jones J. W., Curry R. B., Boote K. and Allen L. H. Jr in *The Potential Effects of Global Climate Change on the United States.* Appendix C Vol. 1 (Edited by Smith J. B. and Tirpak D. A.) (US Envir. Protection Ag. Washington DC, 1989).

[14]Rogers H. H., Bingham G. E., Cure J. D., Smith J. M. and Surano K. A. *J. Envir. Qual.* 12: 569–574 (1983).

[15]Hansen J. et al. *Mon. Weath. Rev.* 111(4): 609–662 (1983).

[16]Manabe S. and Wetherald R. T. *J. Atmos. Sci.* 44:1211–1235 (1987).

[17]Wilson C. A. and Mitchell J. F. B. *J. geophys. Res.* 92(13): 315–343 (1987).

Farm-Level Adaptations

In each participating country, the agricultural scientists used the crop models to test possible responses to the worst climate change scenario (this was usually, but not always, the UKMO scenario; adaptation simulations were done with all three GCMs at some sites). These adaptations included changes in planting date, variety and crop, and applications of irrigation and fertiliser. Irrigation simulations assumed automatic irrigation to field capacity when plant available water dropped to 50% and 100% irrigation efficiency. These optimistic assumptions imply that water supply for irrigation would be fully available at all locations under climate change conditions. All adaptation possibilities were not simulated at every site and country: Choices of adaptations to be tested were made by the participating scientists, based on their knowledge of current agricultural systems.

For the economic analysis, crop model adaptation results were grouped into two levels of adaptation. Level 1 implies little change to existing agricultural systems, reflecting responses to a changing climate that should be easily available to individual farmers. Level 1 adaptations included shifts in planting date (±1 month) that do not imply major changes in crop calendar, additional application of irrigation water to crops already under irrigation, and changes in crop variety to currently available varieties more adapted to the altered climate.

Adaptation level 2 implies more substantial change to agricultural systems, possibly requiring resources beyond the farmers' means, investment in regional and national agricultural infrastructure, and policy changes, although these types of changes were beyond the scope of the analysis. Level 2 adaptations included large shifts in planting date (> 1 month), increased fertiliser application (included here because of implied costs for farmers in developing countries), installation of irrigation systems, and development of new varieties (tested by manipulation of genetic coefficients in crop models). Level 2 represents a fairly optimistic assessment of world agriculture's response to the changed climate conditions tested.

To extend the adaptation site results to national yield change estimates for all the countries in the world food model and to other GCM scenarios, a simplifying assumption was made based on the crop modelling results to halve the negative impact if adaptations partially compensated for the negative effects of climate change, and to set yield changes to zero if compensation was full. If yield changes were positive, adaptation to produce even greater yield increases was not included, with the assumption that farmers would lack incentive to adapt further. This unrealistic assumption tends

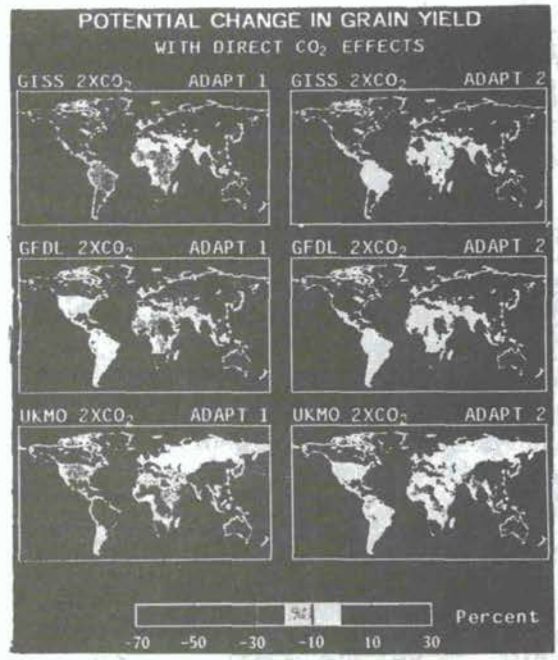

Fig. 3. Estimated changes in average national grair yield (wheat, rice, coarse grains, and protein feed with direct 555 ppm CO_2 effects) under two levels of adaptation for the GISS, GFDL and UKMO doubled-CO_2 climate change scenarios[8]. Adaptation level 1 signifies minor changes to existing agricultural systems; adaptation level 2 signifies major changes. Results shown are averages for countries and groups of countries in the BLS world food trade model; regional variations within countries are not reflected.

to underestimate potential disparities between countries able to improve productivity under the climate change scenarios and countries that cannot fully adapt. The adaptation estimates were developed only for the scenarios that included direct physiological CO_2 effects as these were judged to be most realistic.

Although crop models allow testing of some potential improvements in agricultural production, they do not include yield-enhancing technological developments induced by negative climate change impacts. Level of adoption and efficacy of adaptive practices are also uncertain. There may be social or economic reasons why farmers are reluctant to implement adaptation measures, for example, increased fertiliser application and improved seed stocks may be capital-intensive and/or not suited to indigenous agricultural strategies. Furthermore, such measures may not necessarily result in sustainable production increases (for example, irrigation may eventually lead to soil salinisation).

Yield estimates for the two adaptation levels are shown in Fig. 3. Level 1 adaptation compensated completely for the climate change scenarios, particularly in the developing countries. For the GISS and GFDL scenarios, level 2 adaptation compensated almost fully for negative climate change impacts. With the high level of global warming projected by the UKMO climate change scenario, neither level I nor level 2 adaptation fully overcame the negative climate change effects on crop yields in most countries, even when direct CO_2 effects are taken into account.

World Food Trade Model

The basic linked system (BLS) consists of a set of linked national agricultural sector models.[18] It is comprised of 16 national (including the EU) models with a common structure, 4 models with country-specific structure and 14 regional group models. The political changes as well as changes in national boundaries of the very recent past are not in the BLS, although the model formulation has been adjusted, away from centrally planned economies to more market-oriented behaviour. The 20 models in the first two groups cover ~80% of world agricultural production; remaining 20% is covered by 14 regional models for countries which have broadly similar attributes (for example African oil-exporting countries, Latin American high-income exporting countries, Asian low-income countries). The BLS is a general equilibrium model system, with representation of all economic sectors, empirically estimated parameters and no unaccounted supply sources or demand sinks. Countries are linked through trade, world market prices and financial flows.

The BLS does not incorporate any climate relationships *per se*. Effects of changes in climate were introduced to the model as changes in the average national or regional yield per commodity as described above. Internal economic adjustments occur as increased agricultural investment, reallocation of agricultural resources according to economic returns (including crop switching) and reclamation of additional arable land as a response to higher commodity prices. Improvements in agricultural technology are represented by annual yield trends for developed and developing countries based on historical trends. The BLS contains yield-fertiliser production functions to capture the effects that changes in fertiliser prices and subsequent changes in fertiliser applications may have on yields at the national level. The economic adjustments to climate change simulated by the BLS are assumed not to alter the basic structure of yield-fertiliser functions, even though some of these relationships (for example, yield responses to nitrogen fertilisation) may be altered in a changed climatic regime and under elevated CO_2 conditions.

Summary indicators of the world food system's sensitivity to the climate change scenarios include world cereal production, world cereal prices and population in developing countries (excluding China) at risk of hunger. The "risk of hunger" indicator in the BLS was developed from estimates of the number of undernourished people in developing countries made by the FAO;[19] a cross-country regression was estimated, explaining the number of people at risk of hunger by a measure of food energy availability relative to nutritional requirements.[18] Food availability, in turn, depends on income and price levels. Average and marginal budget shares of consumption categories besides food (for example, housing and clothing) are included in the analysis. We include the risk of hunger indicator to show the possible trends in future food security, realising that more comprehensive measures incorporating other socio-economic variables may be devised.

Here we limit our analysis to results relating to the major cereal food crops, even though the BLS explicitly represents efficiency of feed use and trends in production and consumption of alternative livestock commodities. Thus, the reference case simulates the shift to higher-efficiency feed conversion (poultry over beef) occurring in some developed countries. Beyond the indirect effects of changes in feed costs, livestock production is a significant component of the global food system that is potentially sensitive to climate change because of changes in range-land animal productivity.

World Food Trade Model Scenarios

The Reference Scenario (A Future Without Climate Change)

The reference scenario projects the agricultural system to the year 2060 with no climate change and no major changes in the political or economic context of world food trade (Table 2). Population growth rates were exogenously specified from the medium

Table 2. World growth rates in the BLS reference scenario

Growth rate (%)	1980–2000	2000–2020	2020–2040	2040–2060
Population	1.7	1.3	0.8	0.5
GDP	2.9	2.0	1.5	1.1
Cereal yield	1.2	0.7	0.5	0.4
Agricultural production	1.8	1.3	1.0	0.7

All growth rates refer to world average annual percent growth during the indicated period.

[18] Fischer G., Frohberg K., Keyzer M. A. and Parikh K. S. *Linked National Models: A Tool for International Food Policy Analysis* (Kluwer, Dordrecht, 1988).

[19] Food and Agriculture Organisation. *Fourth World Food Survey*. (UN, Rome, 1984); Fifth World Food Survey (UN, Rome, 1987).

projections of the United Nations to 2025, and from World Bank projections thereafter, resulting in ~10.3 billion people by 2060.[20,21]

Economic growth rates in the BLS are endogenously determined in most of the national models, yielding a moderate projection of world economic growth for the reference scenario. A 50% trade liberalisation in agriculture (for example, removal of import restrictions) is introduced gradually by 2020. The analysis of trade liberalisation is restricted to removal of distortions between trade prices and domestic prices at the level of agricultural raw materials.

Technology is projected to increase yields over time, but at a slowing rate based on historical trends. The rate of exogenous technical progress starts from historical values (1.3% in the 1980s) and for cereal crops approaches 0.5% per annum by 2060. Availability of arable land for expansion of crop production is based on FAO[22] data.

Climate Change Scenarios

The food trade simulations for the three GCM scenarios were started in 1990. The yield changes estimated from the crop model simulations were applied linearly up to 2060 to the yields simulated by the BLS, which include the effect of technological improvement. Although the testing of climate change impacts without farm-level adaptation is unrealistic, it is done for the purpose of establishing a baseline with which to compare the effects of farmer response.

Scenarios Including the Effects of Farm-Level Adaptations

The next step in the analysis involved adjusting the climate-induced yield changes assuming adaptation levels 1 and 2 described above. We can safely assume that at least some farm-level adaptations will be adopted, especially techniques similar to those tested in adaptation level 1. Policy, cost and water resource availability were assumed not to be barriers to adaptation.

World Food Trade Results

The Reference Scenario

Assuming that population growth, economic growth, technological progress and trade liberalisation proceed as specified above without climate change, world cereal production (wheat, rice, maize, millet, sorghum and minor grains) is estimated to grow to 3286 million metric tons (mmt) in year 2060 (compared with 1795 mmt in 1990). Cereal production in developing countries grows to exceed production in developed countries by 2020. Despite slowing gains in yield increases, food production (measured as net calories produced) is projected to exceed population growth throughout the simulation period of the reference scenario.

Cereal prices are estimated at an index of 121 (1970 value, 100) for the year 2060, reversing the falling trend of real cereal prices over the past 100 years. The standard reference scenario has two phases of price development. During 1980 to 2020, while trade barriers and protection are still in place but are being reduced, there are increases in relative prices. This occurs in the short- to medium-term because a removal of subsidies leads to lower farm-gate prices and therefore disincentives to production, while consumers benefit from somewhat lower retail prices, an incentive to demand. In the longer term, price decreases follow due to efficiency gains and technical progress. The number of people at risk of hunger is estimated at ~640 million or ~6% of total population in 2060 (compared with 530 million in 1990, ~10% of total current population).

Climate Change Scenarios

Without direct CO_2 effects on crop yields, world cereal production is reduced by 11 to 20%, and their inclusion brings yield decreases to between 1 and 8% (Fig. 4). The world production changes mask a disparity in response to climate change between developed and developing countries (Fig. 5). The largest negative changes occur in developing regions though the extent of decreased production varies greatly by country depending on the projected climate. By contrast, in developing countries, production is estimated to increase under all but the UKMO scenario.

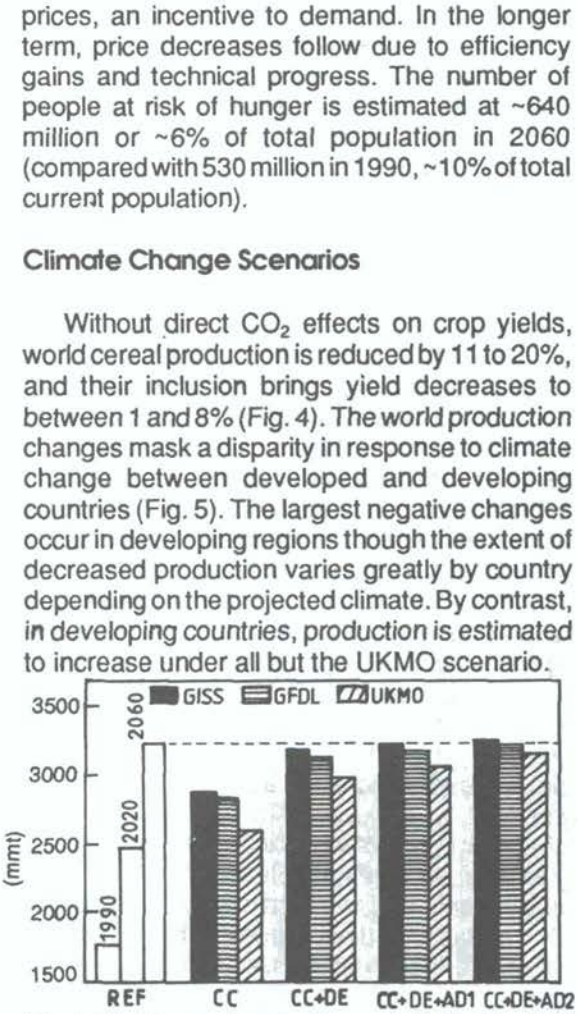

Fig. 4. World cereal production projected by the BLS for the reference, GISS, GFDL and UKMO doubled-CO_2 climate change scenarios, with (CC+DE) and without (CC) direct CO_2 effects on crop yields, and with adaptation levels 1 and 2 (AD1 and AD2). Adaptation level 1 implies minor changes to existing agricultural systems; adaptation level 2 implies major changes. (mmt, million metric tons).

[20] United Nations. *World Population Prospects 1988* (UN, New York, 1989).

[21] International Bank for Reconstruction and Development/World Bank. *World Population Projections* (Johns Hopkins Univ. Press, Baltimore, 1990).

[22] *AGROSTAT/PC* (Food and Agriculture Organisation, United Nations, Rome, 1991).

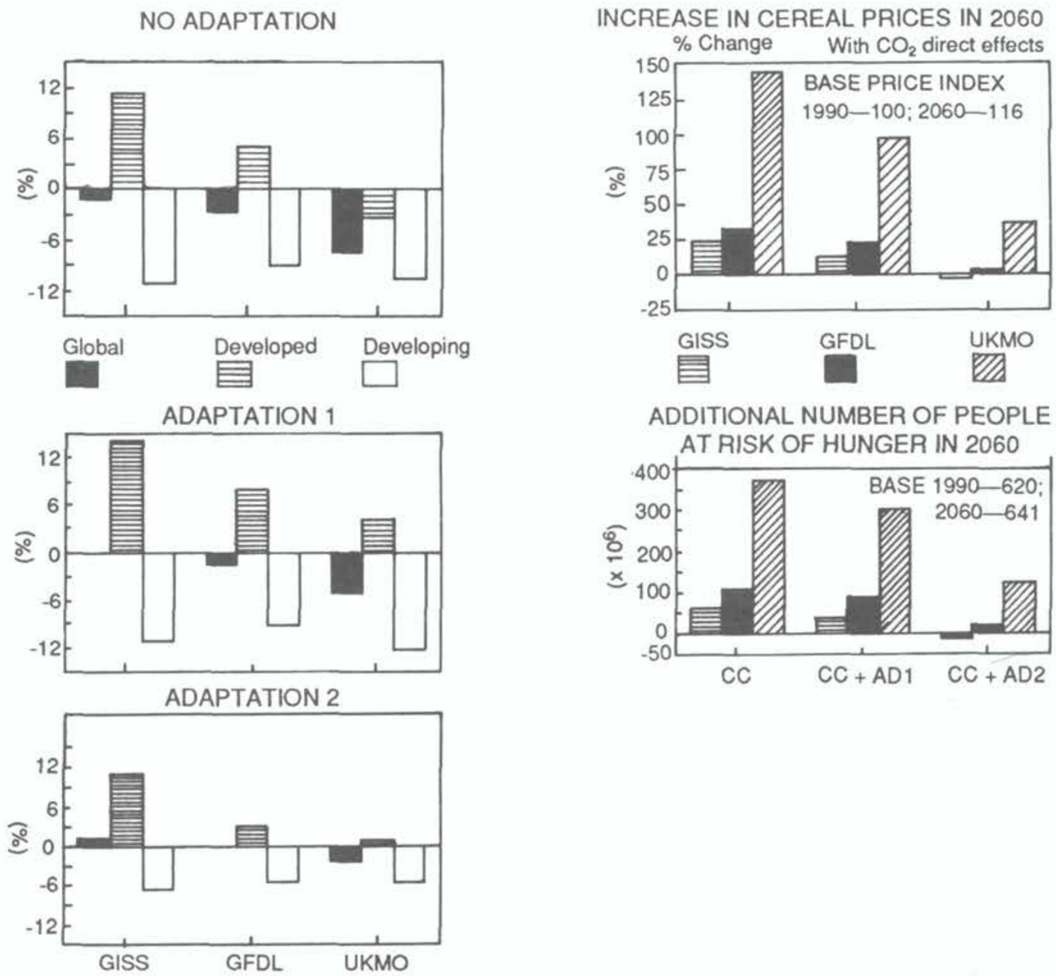

Fig. 5. Change in global, developed country, and developing country cereal production (with direct CO_2 effects), cereal prices, and people at risk of hunger in 2060 for climate change scenarios (CC), and with adaptation levels 1 and 2 (AD1 and AD2). Reference scenario for 2060 assumes no climate change, and projects global cereal production to be 3286 mmt, developed country production to be 1449 mmt, and developing country production to be 1836 mmt.

Price increases resulting from climate-induced decreases in yield are estimated to range between ~24–145% (Fig. 5). These increases in price affect the number of people at risk of hunger. Their estimated number increases ~1% for each 2–2.5% increase in prices (depending on climate change scenario). People at risk of hunger increase by 10% to almost 60% in the scenarios tested, resulting in an estimated increase of between 60 million and 350 million people in this condition (above the reference scenario projection of 640 million) by 2060.

Scenarios Including the Effects of Farm-Level Adaptations

Globally, both minor and major levels of adaptation help restore world production levels (when CO_2 effects are included), compared to the climate change scenarios with no adaptation (Fig. 4). Averaged global cereal production decreases by up to ~160 mmt (0 to -5%) from the reference scenario projection of 3286 mmt with minor level 1 adaptations. With adaptations implying major changes, global cereal production responses range from a slight increase of 30 mmt to a slight decrease of ~80 mmt (+1% to -2.5%).

Level 1 adaptation largely offsets the negative climate change yield effects in developed countries, improving their comparative advantage in world markets (Fig. 5). In these regions, cereal production increases by 4 to 14% over the reference scenario. However, developing countries are estimated to benefit little from this level of adaptation (-9 to -12% change in cereal production). More extensive adaptation virtually eliminates global negative cereal yield impacts derived under the GISS and GFDL climate scenarios, and reduces impacts under the UKMO scenario to one third.

Under adaptation level 1, price increases range from 10 to 100% (Fig. 5). Under adaptation level 2, cereal price responses range from a decline of ~5% to an increase of 35%. As a consequence of climate change and adaptation level 1, the number of people at risk of hunger increases by ~40 million to 300 million (6–50%)

from the reference scenario of 641 million (Fig. 5). With a more significant amount of adaptation by farmers, the number of people at risk of hunger is altered by between -12 million for the GISS scenario and 120 million for the UKMO scenario (-2% and +20%). These results indicate that, except for the GISS scenario under adaptation level 2, the simulated farm-level adaptations did not mitigate entirely the negative effects of climate change on the number of people at risk of hunger, even when economic adjustment, that is, the production and price responses of the world food system, are taken into account.

Discussion

Several major points emerge from this study. Climate change scenarios near the high end of the IPCC range of doubled-CO_2 warming exerted (in most cases) a slight-to-moderate negative effect on simulated world cereal production, even when the beneficial direct effects of CO_2, farm-level adaptations and future technological yield improvements were taken into account. The only scenario that increased global cereal production was one involving major, and possible costly, changes in current agricultural systems, for example, installation of irrigation. Availability of irrigation water, however, was not included explicitly in the study; supplies may be limited under climate change conditions not only for expanding irrigation but for maintaining the current extent of irrigation in some areas. Although the overall results of the study are relatively benign, they depend strongly on the full realisation in the field of beneficial direct physiological CO_2 effects on crop growth and water use as currently measured in experimental settings.

Climate change was found to increase the disparities in cereal production between developed and developing countries. Whereas production in the developed world benefited from climate change, production in developing nations declined. Adaptation at the farm-level did little to reduce the disparities, with the developing world suffering the losses. Cereal prices, and thus the population at risk of hunger, increased despite adaptation. Even a high level of farm-level adaptation in the agricultural sector did not entirely prevent such negative effects. Thus, while some countries in the temperate zones may reap some benefit from climate change, many countries in the tropical and subtropical zones appear more vulnerable to the potential impacts of global warming.

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Land Entitlements, Tenure and Climate Change: The Zimbabwe Case

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Introduction

Zimbabwe is a tropical landlocked country situated in South Central Africa, with a land area of 359,000 square kilometres, located on a high plateau ranging from 197 metres to 2592 metres above sea level. The climate of Zimbabwe is modulated by altitudes, maritime influences and the mid-continental high pressure zone which allows for seasonality in weather. This locational perspective underlies the major climate variability found in Zimbabwe in recent years. The droughts and low rainfall regimes experienced since 1980, reflect cycles of economic "boom" and "bust", in an economy susceptibile to major climate fluctuations.

Agriculture makes a significant contribution to the economy, contributing 40% of inputs to the manufacturing sector and supplies 40 to 50% of exports. Production is diversified and varies according to type of farm practices and region. Whilst historically commercial farmers accounted for the bulk of farm produce in almost all sectors, peasant farmers now produce half of the total marketed cotton crop, maize and 75% of sunflower. But the general theme is that subsistence farming remains paramount in poorer natural regions where the bulk of the population resides.

Land Tenure Regimes

The history of settler emigration in Zimbabwe led to widespread land alienation and marginalisation of the peasantry, and the creation of a land market. Today there are three main classes of land tenure, designated: National (or state) Land, Communal Areas (CAs) and Commercial Land. The following features depict the land tenure regime of Zimbabwe:

State Land

Comprises 15% of the total land area and is generally situated in remote areas. Large tracts of land were gazetted as state forests, botanical reserves, safari areas, recreational parks, national parks and game sanctuaries. Other land was pegged by prospective miners, leading to the emergence of mining towns. Developing concurrently was the process of urbanisation. This land is held in trust by the government for the preservation, conservation and development of natural resources therein. Such land generally does not have market values attached to it.

Communal Areas (CAs)

Formally Tribal Trust Lands (TTLs), accommodate 56% of the population on 41.8% of the land mass. Grazing lands are communally managed, while cropping land is allocated to rural people by District Councils, acting on the advice of Village Development Committees. It is not possible to accurately define arable farm sizes in this area. Dividing total farming area, by the number of families gives an indicative average of about 20 ha per family. But plots of 2 hectares or less are common in the densely populated CAs, while about 10% of the families control over 6 hectares each. The Riddell Commission (1981) depict the communal lands as having exceeded its ecologically safe carrying capacity by some 2.5 times by 1977. Numerically this conclusion accounted for only 2.5 million people then, compared to over 4 million today. These estimates related population density and the agro-stocking rate to the physical carrying capacity of the land.

Commercial Land

36.4 percent of the country is freehold land. It is mainly comprised of commercial farms, (formerly European area) with some small scale commercial farms (formerly the African Purchase Area). The 5000 or so commercial farms generally extend over 1000–2000 ha, but size is related to agro-ecological potential. Farm sizes are larger varying from 2000 to 5000 ha in regions II and IV. Ranches are larger, averaging around 10,000 ha. Cattle ranching although lucrative is an extravagant use of land when there is such land pressure in the country, even though it is the generally accepted ecologically sound land use for NRS IV and V. Yet in the same region, numerous communal farmers strive to survive on land holdings too small to promote sustainable agriculture. There is, however, considerable under-utilisation of land on commercial farms. As much as 1.45 million ha out of 4.3 million ha found in the highest agro potential regions was uncultivated in the 1983–84 census, while approximately 6 million hectares are generally underutilised.

Resettlement Areas

Are the fourth and more recent category of land tenure. They are of political significance and earmarked by government to reduce pressure on land in communal areas. But this programme has enabled only a small proportion of blacks (60 families or 6% of peasants) to move into suitable arable lands. Generally resettlement has occurred on poorer quality lands in NRs III and IV. This development was partly in consequence of the Lancaster House stipulation that land could only be acquired from willing settlers.

The Land Problem

Land alienation and unequal control over land are the key land tenure problem of Southern Africa. The historical process of land alienation which led to present inequitable patterns of land tenure in Zimbabwe is well documented. Land alienation was mainly phased over a 55-year period between 1910 and 1965. In 1911, the Communal Areas held only approximately 22% of Zimbabwe's land, while the BSAC land company held 50% of the land (a variant of "state" property), and private white individuals held 20% of the land. By 1931, whites held 50% of the land under freehold, while the state held approximately 23% of the land, small-scale commercial (black) farm areas held 5% and the Communal Areas held 22% of the land.

By 1965, however, the Communal Areas had increased their holdings to approximately 40% of the land, Purchase Areas (black small-scale commercial farm areas) held below 3% and the state held approximately 15%, while the large private farmers held 45% of the land. Through resettlement, the distribution of land and tenure changed during the 1980s, although to this day most of Zimbabwe's high quality land remains in LSCF or state hands.

Land tenure patterns in Zimbabwe thus changed frequently over 15 year cycles, from massive land dispossession of peasants to the re-allocation of "new" lands to peasants by the state as population pressure and political pressure mounted. The state played a key landholding and allocation role, redistributing land between peasants, black small-scale commercial farmers and large white farmers. Lands held by the state were at times held as "unassigned" land, or reserved for forests and nature, leased out to commercial and small farmers, held as urban land, or used for state agricultural development.

In spite of the dominance of the state in structuring land tenure, problems of land access have led to locally managed strategies of accessing land and forms of land tenure, administration and distribution within Communal Areas. This has led to different forms of land-centred conflicts and ideological discourses, reflected on a national scale in demands for the redistribution of state and large scale commercial farm (LSCF) lands.

The evolution of Zimbabwe's land problem is also associated with the emergence since the 1930s of environmentalist ideologies led by white experts and government officials. Related to fears of growing soil erosion, a range of land use controls and regulations were introduced in Zimbabwe's Communal Lands. These centrally directed controls and regulations of land use, administered by white district officers and collaborating chiefs or headmen, generated political resistance, due to the increased insecurity of land tenure in Communal Areas, among other things. The enforcement, first of physical bundling and other soil conservation measures such as forced tree planting and plantation labour heightened tensions in Communal Areas.

In the 1950s, land use reorganisation under the Land Husbandry Act led to widespread insecurity of land tenure within Communal Areas, and among urban workers dependent on and expecting to retire into Communal Areas. Conservation works, crop husbandry "recommendations" and land use reorganisation, not only compelled additional labour allocations in Communal Areas, but attempted to impose restrictions on the land use rights of peasants.

This process generated various changes in land tenure norms within the so-called "Communal" tenure systems, and generated national level land tenure insecurity among blacks, leading to resistance to land management programmes, and further calls for the return of alienated lands. The liberation war, population growth and increased movements of households within communal areas generated new political and administrative demands for access to land and security of tenure. Thus it can be said that the Rhodesian and Zimbabwean states have acted as the land *real estate agent and trustee* serving the interests of various classes, with prospective white land seekers maintaining the privilege of access to land on freehold property conditions.

Indeed, the colonial state attempted to create a small class of landed black small-scale commercial farmers, under a Native Purchase Area Programme, but this remained a pittance given the more widely based and political demands for land redistribution and security of land tenure rights among blacks in general.

Since 1980 there has been mounting pressure for land reform in terms of land redistribution, land use regulation and tenurial arrangements, emanating from a variety of interest groups and classes seeking access to land. Following a slow pace of land redistribution, a plateau in agricultural growth and growing conflicts over land control within various land tenure regimes, there has been a growth in official interest and among some categories of land users for a comprehensive land reform programme.

The major legacy of Zimbabwe's economic dualism can be found in the polarised land property rights, the associated differential access to state and private, technical and financial resources for land development, and in the centrally domineering administrative regulation of land use, land transfers etc. But the key issue of contention today among various social classes and sectoral interests is access to land: Redressing the inequitable access to land and security of tenure among various landholders. This demand translates into actual threat to "illegally" occupy land owned by state institutions, large farmers and some less densely populated communal farm areas. Illegal occupation and use of such lands by the rural poor has generated widespread squatting, rustling and resource poaching problems. Yet there are also increasing demands for land by black business and farming elites who present compelling pressure on government for a revision of both land tenure policy and present land reform strategy towards market based tenure regimes.

Land Distribution for Agricultural Production

The centrality of land tenure and land distributions cannot be overemphasised in the politics of Zimbabwe. The land issue still draws its significance from the fact that 70% of the total population live directly off the land and most of the economy's industrial development depends on the strength of the agricultural sector. In order to better appreciate the existing land tenure problem, it is essential to understand the broad distribution of land and ownership as well as the quality.

Table 1 shows that 6700 white farmers control 47% of the agricultural land compared to over 900,000 peasant households which hold mostly marginal lands. Although 8500 small scale black commercial farmers hold 4% of agricultural land, there is consensus among many officials and politicians that blacks have been marginalised in agriculture mainly because of the land ownership structure. Yet, by 1986, about 450 blacks had acquired large scale commercial farm lands, although they faced problems such as lack of management skills and indebtedness resulting in inadequate land utilisation.

The dominance of communal lands, occupying 16.4 million hectares or 49% of Zimbabwe and presently supporting 4.2 million people or 55% of the national population, should be thus adequately addressed on the debate on land tenure system of the country. A critical feature of Zimbabwe's land tenure situation is the quality of land available to different groupings with different land use objectives. Table 2 shows the land distribution by farm sector and natural region.

Currently, Zimbabwe is divided into five natural regions on the basis of soil type, rainfall and other climate facets (Box 1). The types and value of farm output in Zimbabwe varies significantly

Table 1. Distribution of land for agricultural production

Owners	No. of farmers	%	Land area (ha)	% Land
Large-scale comm. farmers	6700	0.93	15.5 million	47
Small-scale farmers	8500	1.19	1.4 million	4
Communal area farmers	900,000	97.88	16.4 million	49
Total	915,200	100.00	33.3 million	100

Table 2. Land distribution by the farm sector and NR (ha x 10^6)

	I	II	III	IV	V	Total
Communal land	0.14	1.27	2.82	7.34	4.79	16.36
Resettlement land	0.03	0.59	1.24	0.81	0.62	3.29
Private land	0.21	3.91	2.84	2.90	2.59	12.45
State land	0.33	0.09	0.71	3.73	2.44	6.97
Total	0.70	5.86	7.29	14.78	10.44	39.07

Source: Bradely, 1992.

Box 1. Zimbabwe's five agricultural regions

Natural Region I—5835 sq. km. Eastern Highlands slopes of Manica Province, along the border with Mozambique. High altitude, cool, high reliable rainfall: >1000 mm. Very susceptible to erosion when devegetated. Intensively used for dairying, forestry, tea, coffee, tree-fruit, vegetables and in the valleys, maize.

Natural Region II—72,745 sq. km. Intensively cropped (mainly commercial farmland of northern Mashonaland, occupying much of the northeast quadrant, reliably receiving 700–1000 mm of rain annually. The main area of rainfed maize and tobacco cultivation, and important also for winter wheat, cotton and vegetables. Predominantly LSCFs. Harare lies in this area: So the short-term visitor who sees the city and the airport only can get a false impression of the country as a whole!

Natural Region III—67,690 sq. km. Semi-intensively cultivated areas occupying much of Mashonaland and Midlands Province, receiving 650–800 mm rainfall mostly during infrequent heavy storms. Rainfed cultivation of drought-resistant cotton, soyabeans and sorghum, but water storage and irrigation needed for other crops. High proportion of communal land.

Natural Region IV—128,370 sq. km. Hot, lower-lying land, north and south of the semi-intensively cultivated area. Subject to seasonal drought and having a mean annual rainfall of 450–650 mm. Suited to semi-intensive animal husbandry. Marginal for rainfed maize cultivation (yields are often <0.5 tonnes/ha). High proportion of communal land. Particularly hard-hit by the 1982–84 drought and always vulnerable.

Natural Region V—112,810 sq. km. Without irrigation, this very hot low-lying zone with less than 650 mm annual rainfall, is suitable only for extensive animal husbandry; but the impoundment of Lake Kyle to facilitate extensive irrigated cultivation of sugarcane in the south-eastern lowveld and intensive wheat production at Chisumbanje. A smaller similar region in the north, below the Zambezi escarpment, is drought-prone and infested with tsetse fly.

among these five natural regions (Table 3). These regions generally translate into two major categories of farming systems: the rich commercial large scale farms (SCFs) and at the other end of the ladder the communal farms areas (CAs).

The agro-ecological land distributional problems of Zimbabwe, where blacks are disadvantaged are not a coincidence but emerged out of planned land re-allocation by the colonial regime. The distributional pattern was salient on the question of gender. While it is generally accepted that men are central heirs and holders of land rights in the patrilineal communities, access to land is not easily conferred on single, married and divorced women.

Perceptions of Zimbabwe's land problem have therefore tended to change, as inequitable land distribution remains and black entry into the LSCF exposes weaknesses in black agriculture such as slow growth in productivity, failure to penetrate high value commodity production and the slow adoption of technology. Increased state controls over various lands, land hunger, and rural poverty have also led to new land-based conflicts, as the changing use-value of land, including tourism uses, changes the nature of the demand for land in the wider rural and urban population.

Agricultural Productivity Among the Poor

The broad objective of land reform will be to improve land management capacities and roles of all landholders. Land access inequality tends to be justified by ascribed and perceived land management roles and contributions, different landholders: The state is the protector of nature and a sustainable user, the LSCF is the agricultural market provider and the communal areas are the subsistence (social security) maintenance guarantors (with some "surplus" marketing).

A key argument developed here is that the issue of land policy in Zimbabwe has been focused mostly on an inadequate analysis of availability of land for distribution, and an inaccurate assessment of the demand for land and related issues. This gap is greater land underutilisation. But the growth in peasant outputs suggest increased cultivation of marginal lands. Moreover, peasants and small-scale farmers, and later resettlement farmers, received minimal state support. From the 1930s up to the present, macro-economic and agricultural policies protected LSCF access to capital, technology, foreign currency and commodity markets. Discriminatory agricultural commodity pricing, state marketing, state credit, import regulations, access to foreign currency and irrigation support were and are key policy instruments used to productivity growth. Nevertheless, the LSCF had failed to achieve optimal levels of land utilisation, due to the high capital and management costs of operating farms averaging 2000 hectares per owner, with some owning multiple farms.

Thus much of the productivity debate has a clear racial connotation: The race issue is central to the productivity discourse because to date the entire agricultural sector is still divided between African and white farmers. The terms, "large scale", and "commercial" are synonymous with

Table 3 (a) Efficiency and arable land use for crop production

	Total area ('000 ha)	Arable land ('000 ha)	Arable land (%)	Crop area[d] planted ('000 ha)	Cropping efficiency (%)	Net arable land ('000 ha)[e]	Net cropping efficiency (%)	Adjusted[f] crop area ('000 ha)	Adjusted crop eff. (%)
	A	B	C = B/A	D	E = D/B	F	G = D/F	H	I = H/F
Mashonaland West	1886.0	760.6[a]	40.3	184.6	24.3	650.3	28.4	270.2	41.6
Mashonaland Central	732.6	307.3[a]	41.9	105.4	34.3	262.7	40.1	152.7	58.1
Mashonaland East	957.8	522.1[a]	54.5	97.6	18.7	446.4	21.9	139.1	31.2
NR I	202.2	27.9	13.8[b]	11.7	39.7	23.9	49.0	12.1	50.6
NR II	3686.9	1047.1	28.4	379.1	36.2	895.3	42.3	556.0	62.1
NR III	2405.4	574.9	23.9	48.4	8.4	491.5	9.9	74.9	15.2
NR IV	2429.1	10.1[c]	0.0	8.9	88.1	10.1	88.1	10.2	101.0
NR V	2489.7	102.5[c]	0.0	52.3	51.0	102.5	51.0	53.1	51.8

a = Adapted from Weiner et al. (1985) less land acquired for resettlement, assuming that 1988 totals contain the same proportion of arable and non-arable land as in 1981.
b = Percentages for natural regions are adapted from Vincent et al. (1962, p. 170).
c = Arable land is irrigable lands times cropping intensity of two.
d = Crop area in 1988–89, CSO.
e = Arable land less 10% for squaring of fields, tree lines, roads, homesteads and pockets of inaccessible land.
f = Crop area adjusted to include recommended fallow rotations.

Table 3 (b) Grazing land efficiency

	Total area ('000 ha)	Crop area planted ('000 ha)	Crop area less fodder ('000 ha)	Unusable land ('000 ha)	Grazing area ('000 ha)	Livestock units ('000 LSU)	Low risk grazing area/LSU (ha/LSU)	Mod. risk stocking strategy (ha/LSU)	High risk stocking strategy (ha/LSU)	Stocking strategy (ha/LSU)
	A	B	C	D	E = A-C-D	F	G = E/F	H	I	J
Mashonaland West	760.7	43.6	40.0	152.1	586.6	67.5	8.4			
Mashonaland Central	3576.5	387.7	343.2	715.2	2518.1	570.9	4.4			
Midlands	1689.1	18.1	15.6	337.8	1335.7	215.8	6.2			
Masvingo	2406.7	41.8	40.7	481.3	1884.7	153.5	12.3			
Matebeleland	2780.4	9.4	6.8	556.1	2217.5	254.4	8.7			
NR I	202.2	11.7	10.5	40.4	151.3	23.3	6.5	3–4	2	1
NR II	3686.9	379.2	334.1	737.4	2615.4	545.3	4.8	3–4	2	1
NR III	2405.5	48.4	43.3	481.1	1881.1	295.7	6.4	6–8	3–4	2
NR IV	2429.1	8.9	6.2	485.8	1937.1	196.6	6.5	8–10	4–5	3
NR V	2489.7	52.4	52.2	497.8	1939.7	101.2	19.2	10–15	5–8	4
National	11213.4	500.6	446.3	2242.5	8524.6	1262.1	6.8			

World Bank: Agriculture Sector Memo; 1991.

white farmers, while the words "communal", "resettled" or "peasants" refer to African farmers.

As a result, the productivity debate continuously sparks questions about the government autonomy from the pressures of the CFU as well as the government's genuine fear of loss of agricultural productivity. The CFU has used the productivity issue as a means of putting political pressure on the government.

The major question that the government needs to assess is whether or not redistributing land will necessarily induce a decline in agricultural productivity. The major proponents of the productivity issue argue that government cannot take the chance of short or long term loss in productivity.

Thus the government has promised not to take more land from **commercial farmers than these farmers need to produce current outputs,** and to give communal farmers only underutilised land. The LSCF sector is seen as economically critical by the government because of its ability to contribute both domestic and foreign exchange earnings. Yet the problem of social reproduction of the rural poor rests on the redistribution of LSCF lands.

The Benefits of Land Redistribution

There are both political and economic benefits to increased land reform. Since 1992 the government has been indecisive about redistributing land although the head of the state has argued in historical context, that land redistribution was fundamental and had to be implemented speedily. Government rhetoric emphasise the important role that land plays in reconciling blacks and whites, in resolving the National Question by providing land rights for the majority and in guaranteeing the rural poor the basic means of survival. Thus officially land redistribution is seen to anchor the role of the state in adjudicating over, not only the rights of land owners, but also the land rights, needs and demands of the "voiceless" rural majority.

The economic rationale of land redistribution goes beyond the static numbers game of protecting currently cropped hectares from being transferred to blacks. Firstly, black output in resettlement has not been as disastrous as claimed by many. Such output can be improved as small farmers gain access to financial resources, equitable access to input markets and expertise.

The fundamental economic rationale is to broaden the incomes base of Zimbabwe, through an expanded farming structure based on increased access to land. This can widen the markets available to industry and the rural service sector and increase food and raw material supplies. Thus the state will play a critical role in the allocation of finance, forex, imports and other incentives to black farmers. This in a way will alleviate rural unemployment as the concentration of rural incomes among a few farmers is largely based on unavailability of land to blacks, when most of the prime land is largely underutilised.

Thus land redistribution whether conceived in economic or political terms cannot reasonably overlook the need to provide access to land for the numerous peasants in overcrowded areas. Indeed, redistributing land to other rural people besides the "capable" farmers, is justified for economic and social reasons. The economy cannot employ all adults in the urban economy or on commercial farms, nor can the state afford to feed all the rural destitutes. As a matter of fact, apart from the fact that such socially derived settlers could be supported to improve productivity their unrecorded output contributes to national Gross Domestic Product and thus performs the vital function of producing labour for the economy, based on auto-consumption from small patches of arable land.

An economic argument, which is used as a condition for further resettlement is the proposal that communal and resettlement areas need to be provided with freehold land tenure because investment and growth in agriculture cannot proceed without absolute land ownership rights. Title deeds held on land are an advantage for those seeking loans in the present conservative money markets. Research also shows that farm investment and access to farm credit tend to thrive where tenure is secured through various types of titles including leases, permits and customary rights. However, title deeds did not guarantee optimal farm investment as evidenced by the failure of large commercial farms to fully develop or utilise their land.

It appears that the political problem facing Zimbabwe with regard to land and similar resource ownership imbalances is the absence of good faith on the part of land owners in negotiating and redressing the land imbalances. That all Zimbabweans cannot be commercial or peasant farmers is quite obvious. What is unclear is where and how rural and the urban landless can be accommodated without land redistribution and a concomitant industrial growth, given also that commercial farming has increasingly mechanised and shed approximately 30% of its labour force in the last 15 years.

Historical grievances over land dispossession and the present inequity in land holding, are real political sentiments fuelled by the absence of alternative economic opportunities. Slow economic growth requires that land be used now by the numerous unemployed and landless for their survival and contributions to national outputs and self-employment. This is a political problem which government must face with courage rather than with doubts emanating from the pretentious "de-politicisation of land" by politically motivated opponents of land redistribution.

Land Equity and Climate Change

Thus the land question is an intrinsic, non-partisan issue that many Zimbabweans wish to see addressed. It makes no sense, however, to pretend that the land question is not a political issue, and that it should only be addressed following purely economic logic, particularly of a short-term nature. The land issue is a political issue that has to be addressed with full cognisance of the political problems it evokes, but in a manner which optimises the economic benefits to the country. Therefore any party that will move fast with land redistribution need not apologise for the utility of resolving the land question in its bid to be elected or re-elected.

Yet the environmental debates, including those which deal with climate change also tend to offer narrow techni rationale for retaining inequitable land tenure regimes. Unequal land control patterns, and market led land tenure systems, which reinforce inequitable access to land are implicitly the preferred options for those environmentalists who see social development as secondary to land management and climate change. Yet the evidence reveals that not redistributing land leads to greater political conflict and hence economic instability, greater poaching of land and natural resources hence insecure land management systems, and increased social deprivation which feeds the over-utilisation of the meagre land and natural resources available to the rural poor. The choice is between planned transfer and management of resources by the majority poor, and the systematic onslaught on unequally controlled land resources.

In a situation such as is found in Zimbabwe, land redistribution can lead to the enlarged use of previously underutilised land resources. This implies greater disturbance of the land and biomass systems which affect climate change. Yet given access to better land, the poor can improve their productivity on less land, can improve their management of biomass resources given the greater potentials of NR II and III, and improve the non-farm economy based on increased output. These are critical tradeoffs which can be mitigated rather than land redistribution for fear of climate change.

Role of Governance, Accountability, and Care Responsibility

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Introduction

Indonesia attempts to reconcile development with environmental protection under the concept of sustainable development. The goal of sustainable development is to maximise the next benefit from sustainable resources use, subject to maintaining the services and quality of the resources over time and intergeneration.

Development policies of the Republic of Indonesia are based on Trilogi pembangunall (Three principles of development). These are:

1. Balance development and its product aim to social equity for all of the people.
2. High economic growth.
3. Dynamic national stabilisation.

As a developing country which has an archipelagic islands character and is located on the Equator, Indonesia has an important and strategic geographical role and cannot free itself from the influence of global environment, i.e., global warming and the adverse effects of climate change that result from an increase in greenhouse gases concentration in the atmosphere. Global warming and the climate change is not only the responsibility of one sector or certain sector but all of the development sectors.

It is realised that the adverse affects of climate change resulting from greenhouse gases is a unique and complex concern and that there is still uncertainties from the point of scientific knowledge, the economic implications and the choices for anticipating its effect. National development strategy, and its action which takes into account the importance of the aspect of climate change for environmentally sound sustainable development, is definitely needed. But the improvement of climate data and scientific knowledge about the complexity of climate change at national level should be strengthened.

The principles of equity and justice as well as that of collective or joint responsibility among the government, private sector and populace are basis for the success to anticipating the climate change resulting from greenhouse gases.

Role of Governance to Maintain the Equity Within Country in the Socio-Economic Context of Climate Change

Indonesia has recognised the importance of climate change and of having national strategy to cope with it, as demonstrated by establishment of the National Committee on Climate Change and the National Strategy for Anticipating Climate Change Resulting from Greenhouse Gases. This report is intended to strengthen the foundations of that strategy. The backbone of this national response strategy are the adaptation and mitigation measures. They must be grounded in a single united approach to the entire problem and backed up by various supporting resources.

Indonesia as a developing country which is still low per capita income and is still to push high economic growth logistically, financially, and institutionally is not yet capable to implement fully the recommendations to reduce the emission. Thus it is proposed that the strategy will favour adaptation over mitigation and preventative over curative action. To select options on the basis of their ecological implications and cost-benefit analysis, to behave in a risk-averse fashion, and to prioritise action on the basis of a national development needs for weighing the relative severity of various impacts are the objectives that should be set up.

The State Ministry for Population and the Environment of the Republic of Indonesia established the Committee for Monitoring and Evaluating the Impacts of Climate Change on 24 January 1990 (Ministerial Decree 07/MENKLH/ 1/90). This committee recently renamed the National Committee on Climate Change in Indonesia and hereafter referred to as the National Committee was charged with investigating the impacts of climate change and other related issues. Indonesia also ratified the Vienna Convention and the Montreal Protocol on May 13, 1992 (Presidential Decree No. 23 of the year

1992). The ratification of the United Nations Convention on Climate Change had been approved on 28 June 1994 by the Parliament and is to be issued as a law.

The integrated sectoral effort will require focused attention and coordination to mitigation and or adaptation of the emission policy. The National Committee on Climate Change has recognised this importance, hence through a Ministrial Decree endorsed its establishment and further is empowered with the necessary financial resources and institutional support to coordinate synchronised and collaborative efforts among government bodies, businesses, non-governmental organisations (NGOs), and the public.

In general, contributors responded positively to the idea of using economic instruments to address the problem of climate change. However, it is unlikely that economic instruments will be applicable to all circumstances. Some combinations of economic and non-economic measures will probably be the most appropriate in the final analysis. Four economic instruments were identified that can affect for national action:

1. Tradeable emission permits
2. Taxes or levies
3. Subsidies
4. Sanctions.

Non-economic criteria such as social equity, fairness, administrative feasibility, and social acceptability are as important as economic ones to be assessed in the adoptation process. According to the situation in which the nation is placed, government might be advised to adopt "non-economic" instruments which are practically feasible and socially acceptable and which can be applied either independently or in combination with market-based economic instruments.

Expanding scientific knowledge and technology in the system of monitoring of the climate change of investigation of its impacts, as well as related research is required. In that matter, it is hoped that in the future the Meteorological and Geophysical Agency (BMG) will have a stronger role as the climate data centre for a system of monitoring and cooperation with other institutions, such as Technology Assessment and Application Agency (BPPT), National Agency for Aeronautical and Space Research (LAPAN), and various related Agencies in the educational and scientific field, and in the technical agencies such as agriculture, public works, forestry, etc.

Accountability Issue at the National Level

Climate change will alter the daily lives of millions of Indonesians by threatening everything from the impacts to rainfall pattern, to agricultural production, adequate food and water supplies, to ecotourism revenues, reverberating throughout the natural and socio-economic environments, sea level rise, increased temperatures, and disrupted rain cycles that will affect coasts, river basins, and upland areas. Agriculture, fisheries, and other sectors which are central to Indonesian culture, subsistence, and economy will be particularly sensitive to these changes.

Given its small contribution to greenhouse gases concentration, Indonesia alone can do little to mitigate climate change. Adaptation efforts are likely to be of more benefit to the country. However, if Indonesia intends to participate in global efforts to mitigate climate change, its citizens may be asked to expend billions of dollars and further to alter their behaviour through significantly modifying their agricultural practices, land use allocations, industrial practices, architecture, electricity generation technologies, transportation systems, and energy consumption levels and patterns.

To anticipate climate change, Indonesia's development should be extended more feasibly, in its relevance to social, economic and environmental policies. It is Government responsibility to promote and cooperate in scientific, technological, technical, socio-economic and systematic observation and development of data archives related to the climate system.

In the national implementation for anticipating the change resulting from greenhouse gases, it is necessary that there are concrete adoption steps to lead to the voluntary reduction of net emissions from all activities that make a contribution to greenhouse gases. For that goal it is necessary that there be an integrated programme for implementation of the mentioned strategy, including the importance of funding that should be sufficient for the needs of its investigation, transfer technology, monitoring and implementation.

Adverse effects of climate change means change in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems.

A global warming due to the increasing atmospheric CO_2 concentration will also bring about a change of climate especially rainfall pattern in Indonesia. The results of simulation of the climate variability under a double atmospheric CO_2 environment showed that air temperature will change by 1–1.4%. In general a location with a mean temperature of, say 26.4°C will experience an increase of 3–4.2°C.

The erosion may increase sedimentation in rivers, waterways, reservoirs or harbours. These may decrease rivers and reservoirs capacity, which in turn may cause flood problems in rainy season. The increasing erosion rate due to the climate change will have a substantial effect on socio-economics of the societal and policy responses of the government. The erosion will decrease land productivity, farmers' economy and welfare.

Climate change will affect Indonesia's marine ecosystem in terms of sea water warming of 0.2 to 2.5°C. Sea temperature rise may diminish the growth rates, vitality and reproductivity rates of many marine species including coral reef. Surface warming may affect water circulation, segmenting food chains, destruction or redistribution of wet species' spawning, breeding, and nursery grounds. Sea level rise may also inundate the brackish water shrimps and fish ponds.

The tourism business in Indonesia will also be at risk when global warming occurs. The beautiful beaches on the southern and eastern coasts of Bali are among the most vulnerable coastlines in Indonesia. Based on the physical impact upon the marine tourism areas identified as vulnerable and the approximate value of economic activities generated by tourism there, climate change is expected to cost the tourism industry US $ I billion. That phenomenon also occurs in the Southern Java and Western Sumatra coasts.

Care Responsibility

The government of Indonesia in 1991, under the leadership of the Ministry of State for Environment, took the first fundamental step to address the issue. An established National Committee on Climate Change consisted of the representatives of departmental and non-departmental agencies, universities, research institutes and non-governmental organisations. The committee succeeded to develop what is called the National Strategy to cope with Global Warming and Adverse Effects of Climate Change, which provides a basic policy framework of response measures against the global warming and climate change in Indonesia.

Indonesia is concerned on the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their command but differentiated responsibilities and respective capabilities between countries. Accordingly, the developed country should take the lead in combating climate change through given priority for emission reduction and the adverse effects thereof.

Policies and measures dealing with climate change such as energy efficiency appropriate sustainable forest wood resources etc., should **be cost-effective to ensure global benefits at the lowest possible national cost.** To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors. Efforts to address climate change may be carried out cooperatively.

Indonesia promotes sustainable development approach in all development sectors. Policies and measures are to protect the climate system against human-induced and integrated with national development programmes, taking into account that economic development is essential for adopting measures to address climate change.

For championing the climate change issue, Ministry of State for Environment promotes and cooperates in education, training and public awareness related to climate change and encourages the widest participation in this process, including that of communities, government institutions at all levels, and NGOs.

While this is not strictly a community response, it lays the necessary groundwork for farmers, fishermen, businesspeople, real estate developers, medical practitioners, and the whole host of people who will be affected by climate change. There is no justification yet for requiring people to take part in mitigation programmes which require them to sacrifice their freedom of choice and welfare merely for the benefit of the industrialised world. However, these are public awareness campaigns directed towards vulnerable populations, transparent adaptation policy planning, and effective pricing policy. Raising public awareness of environmental issues would also foster altruistic participation in climate change adaptation and mitigation.

Indonesian people will be interested and able to respond to the climate change only to the extent that they are informed of and able to participate in the development of response strategies. Further the government alone cannot prevent or prepare for climate change. The massive effort required will necessitate the energy and dedication of Indonesian, and indeed international society as a whole.

As a nation of tropical forests, Indonesia has an important role with regard to global and regional climate. The implementation on re-greening as well as of afforestation, will be continued and should be carried out consistently with the results of analysis and the goal of reducing the total amount of CO_2 in the atmosphere in linkage with the potential of forests as CO_2 sinks. The activities mentioned above are also directed toward supporting the creation of a process of continuous harvesting of forest products.

In the forest sector, mitigation options fall into three categories: reducing emissions, maintaining existing carbon sinks, and expanding carbon sinks. Overall, the best mitigation options in this sector appear to be sustainable forest management, reforestation, and agroforestry. Policy options to support these techniques include conscientious observance of land use designations and borders, development of tree plantations and promotion of participatory forest management (i.e. involving local communities in forest-based activities).

Conclusion

Within National Policy Guidelines on sustainable development in 1993 was already fully considered the National Development Strategy for Anticipating Climate Change that should be implemented to reach the United Nations Framework Convention on Climate Change objectives.

The role of the National Committee on climate change is as a coordinating forum for discussing and composing of national strategy to cope with global warming and adverse effects of climate change. The principles of equity and justice as well as that of joint responsibility among the government, private sector and populace form the basis for anticipating the climate change resulting from greenhouse gases.

Programmes of research and human resources requirement become important and require support so that technology transfer, fund supports, education and training, and gaining popular awareness are maintained.

It is necessary that there is broad research and assessment regarding the analysis of the impacts of climate change from the point of view of socio-economic analysis, both sectorally and subsectorally as well as regionally and nationally. The assessment should discuss the benefits and cost in the steaming of the problems in order to anticipate the impacts of climate change.

Finally on this important occasion, Indonesia is expecting that IPCC can take more roles and to develop more detailed analysis on the integrated assessment at national, regional and global level.

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Trade and Welfare Effects of Policies to Address Climate Change

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Abstract—One commonly suggested approach to curbing world greenhouse gas emissions requires that each country reduce emissions by a given percentage from a base period level using a carbon tax. Although easily understood, it can be demonstrated that such an approach is both less efficient and less equitable than a cost minimisation approach such as a tradeable quotas scheme where the initial allocation of permits could effectively allow compensation of potential losers. It is assumed that Annex 1 countries introduce such policies. The trade and welfare effects of the two approaches are compared using the comparative static version of a multi-region, multi-commodity, computable general equilibrium model—MEGABARE. Particular attention is given to output, net trade and income effects in energy and energy intensive processing industries in Annex 1 and non-Annex 1 countries. It is found that if Annex 1 countries were to all reduce emissions by 20%, all non-Annex 1 countries would be adversely affected. The welfare of all countries could be improved if Annex 1 countries operated a tradeable quota scheme and engaged in joint implementation projects with non-Annex 1 countries.

1. Introduction

There is widespread concern that increasing atmospheric concentrations of greenhouse gases could lead to climate change with possible adverse effects on human health, the environment and climate sensitive sectors of the global economy. This concern about the risks of an enhanced greenhouse effect has stimulated economic research into various policy measures to reduce world greenhouse gas emissions. Proposed policy measures to reduce greenhouse gas emissions are based either on regulatory standards or market based mechanisms or are based on a mixture of the two approaches. Regulatory standards require all polluters to meet the same standard of emission control, regardless of the relative costs of control. In contrast, market based mechanisms such as emission taxes and tradeable emission quota schemes, alter market price signals to ensure that producers and consumers face cost incentives to control emissions at least cost to the community.

Since the greenhouse problem is a global problem, use of market mechanisms would suggest that greenhouse policies should be chosen to minimise the global cost of emission reductions. This could be done by concentrating emission cuts over time between countries where emission cuts are relatively cheap. A fundamental characteristic of the greenhouse problem is that some countries are likely to benefit under a cost effective response to greenhouse risks while other countries are likely to lose. Hence, there will be a tendency for countries to participate in a collective agreement only if they are better off by doing so. Consequently, some kind of compensation will be needed to ensure that countries with large shares in global greenhouse gas emissions, particularly those with low abatement costs, participate in an international agreement and adhere to commitments.

Much of the attention of economic research into greenhouse gas abatement has focused on the wider costs and benefits of abatement policies, with relatively limited emphasis on the trade and welfare effects of such policies. In this paper, the focus is on the trade and welfare affects of policy options to curb world greenhouse gas emissions.

Following the signing of the 1992 Framework Convention on Climate Change, the world can be divided into Annex 1 countries (the OECD, former Soviet Union and Eastern and Central Europe) and non-Annex 1 countries (Stuart, 1994). Annex 1 countries have made a much firmer commitment to reducing emissions than non-Annex 1 countries. Two policy simulations are undertaken in this study. The first involves a 20% reduction in carbon dioxide emissions by each Annex 1 country. The second involves a tradeable quota scheme among Annex 1 countries to achieve the same reduction in global emissions as the equal 20% reduction scheme. For the purposes of the simulations reported here it is assumed that

Annex I countries are also permitted to engage in *joint implementation projects with non-Annex 1* countries. At this stage it is yet to be decided whether Annex 1 countries will be permitted to undertake joint implementation projects with developing countries.

It would be expected that there would be an efficiency gain from the tradeable quotas scheme with joint implementation. Such a scheme approximates a global tradeable quota scheme and would tend to result in the marginal costs of abatement being equalised across emission sources. This represents the least cost way of reducing emissions. In contrast an equal percentage reduction in emissions across countries is a purely arbitrary rule not based on economic efficiency.

In this paper the trade and welfare effects of these specific policy options are analysed using the comparative static version of ABARE's general equilibrium model of the world economy known as MEGABARE. Global general equilibrium models (such as MEGABARE) are particularly useful for analysing greenhouse gas issues. Several of these models ranging from the GREEN model (Burniaux et al., 1992) to the G-cubed model (McKibbin and Wilcoxen, 1992) have contributed to the understanding of the complex interaction associated with greenhouse policy options. In global general equilibrium models, the world economy is divided into a group of countries/regions and each country/region into a collection of independent sectors, which interact through markets for goods and services. By modelling the decisions of households and firms, these models are able to capture the economic mechanisms that link different sectors and also the interactions between countries/regions when examining a new policy such as a carbon tax. These models can also be used to illustrate quantitatively the potential savings from the use of cost effective greenhouse policy.

The paper is structured in the following way. In the next section a brief review of the basic features of the abatement policies outlined above is given. A brief overview of the MEGABARE modelling framework is provided in the third section. In the fourth section, the trade and welfare effects of the proposed abatement policies are discussed. In the final section some policy implications are considered.

2. Carbon Taxes and a Tradeable Emissions Quota Scheme: A Brief Overview

There has been an extensive discussion of carbon tax and tradeable quota schemes in a partial equilibrium framework with fixed prices and price-taking behaviour by decision makers. It is well known that both policies will minimise the costs of achieving a given reduction in emissions by equalising the marginal costs of abatement across regions. All regions may not receive benefits in proportion to their share in the costs of reducing emissions. However, it will be possible to allocate quotas or distribute tax revenue in such a way as to compensate regions for differences between their costs and the benefits from reducing emissions.

The main results of this partial equilibrium analysis essentially carry over to a general equilibrium framework with international trade but the analysis is more complex. In most partial equilibrium models, the welfare of countries is linked only through their level of emissions. In a general equilibrium framework, international trade creates a further linkage. Different settings of policy instruments will affect the terms of trade facing different countries and, hence, their relative levels of welfare.

Emission reduction will affect the pattern and volume of international trade as well as the relative prices of goods. Thus, emission reduction by one country will have welfare effects on other countries through international trade. Furthermore, the extent of these effects will vary with the level of emission reduction undertaken by other countries.

The initial allocation of quotas or tax revenue also plays a more complex role in a general equilibrium model of international trade. In a partial equilibrium model with fixed prices, the allocation of tradeable quotas can play the role of a lump sum transfer. The allocation of quotas is a means of re-allocating a given volume of world production between countries. In a general equilibrium model of international trade, a lump sum transfer between countries could be said to occur if a gift of a basket of goods and services from one country to another satisfied a particular condition. The condition is that if the recipient country placed the gift of the basket of goods and services on the market, it would buy back exactly those goods and services (Dixit and Norman, 1989). Equilibrium world prices would have to change to support the new distribution of goods between countries. Since an international trade equilibrium is a competitive equilibrium, the condition that no retrade occurs is the condition that the new allocation lies on the Pareto efficient frontier.

The initial allocation of quotas or tax revenue may have considerable international trade repercussions. A country with an allocation of quotas surplus to requirements or an allocation of tax revenue greater than payments will be able to use the revenue from quota sales or surplus tax revenue to increase imports relative to exports. Countries in the reverse position will have to increase exports relative to imports. Different allocations of quotas or tax revenue will result in different international trade equilibria and different international distributions of income.

In the literature, many rules for the initial allocation of quotas or tax revenue have been proposed with the purpose of achieving various welfare aims. International trade repercussions of these rules have usually been ignored. It may often turn out that the post trade welfare effects of these rules are quite different from those intended.

The analysis of the effects of the initial allocation of quotas or tax revenue is analogous to that of reparations payments. The effects of such payments has long been discussed in the international trade literature. At issue was whether it was possible for a country making reparations payments to be made better off through the effect of the payments on its terms of trade. For example, reparations payments might result in an increase in demand for exports from the donor country and improve its terms of trade. It is now well established (Dixit and Norman, 1989) that if conditions required for the stability of equilibrium hold, the donor country will always be made worse off and the recipient better off. Nevertheless, there may be considerable international trade repercussions from reparations payments or the allocation of quotas or tax revenue.

Both the level of emission reduction and the way in which quotas or tax revenue are allocated may have considerable feedback effects on the welfare of different countries in a world with international trade. The optimisation problem will be to determine simultaneously the optimal level of global emissions (and, hence, the quantity of quotas to issue or the level of a uniform tax) and the allocation of quotas or tax revenue to maximise a given social welfare function. The social welfare function might involve the sum of the welfare functions of all countries with given weights attached. It is clear that a general equilibrium model of international trade is an indispensable tool in such policy analysis.

3. MEGABARE Modelling Framework

MEGABARE is a multi-commodity, multi-country general equilibrium model. In MEGABARE 37 sectors and up to 18 regions are distinguished. A key building block for MEGABARE is the general equilibrium international trade model known as GTAP (Global Trade Analysis Project) (see Hertel and Tsigas, 1993 for a detailed description of the standard GTAP model). The MEGABARE model has three primary factors—labour, capital and land. Labour and capital are inter-sectorally mobile while land is specific to agriculture. It is also assumed that there is a fixed factor of production in coal, oil and gas, reflecting the extractable quantity of the resource and the sunk capital used in its extraction. For the purpose of this study the MEGABARE database is aggregated to 12 regions and 16 sectors (See Appendix A). A brief overview of the MEGABARE model's economic structure is given below.

Production

Producers in each country/region are assumed to be price takers in both input and output markets, and their technology is characterised by constant returns to scale. The industry technology for current production in the MEGABARE model is depicted in Fig. 1. Producers choose their input mixes to minimise costs subject to the production function described by levels 1, 2, 3, 4 and 5 of Fig. 1.

At level 1, imported intermediate inputs from different sources are assumed to combine within a constant elasticity of substitution production process yielding an aggregate imported intermediate input. At level 2, the aggregate imported intermediate input and the domestically produced intermediate input are assumed to combine within a constant elasticity of substitution production process to yield an intermediate input. At level 3, all composite intermediate inputs are assumed to combine in fixed proportions. At level 4, primary factor inputs are assumed to combine within a constant elasticity of substitution production process yielding a composite primary input. At level 5, it is assumed that producers will use intermediate inputs in fixed proportion to industry outputs and the composite primary factor input.

An important feature of production in the MEGABARE model is the way in which information about available technologies in the energy intensive electricity industry is incorporated. For example, in the electricity industry, output is produced using the conventional intermediate inputs and a special kind of input defined here as the "technology bundle" (see Fig. 2). In Fig. 2, level 1, five different types of technologies are assumed to combine within a CRESH (Constant Ratios of Elasticities of Substitution, Homothetic) production process to yield the "technology bundle". The five technologies distinguished here represent the different technologies in electricity generation using coal, oil, gas, nuclear and other (consisting of hydro, solar and geothermal). At level 2, intermediate inputs and the "technology bundle" are assumed to be used in the electricity industry in fixed proportions to industry outputs.

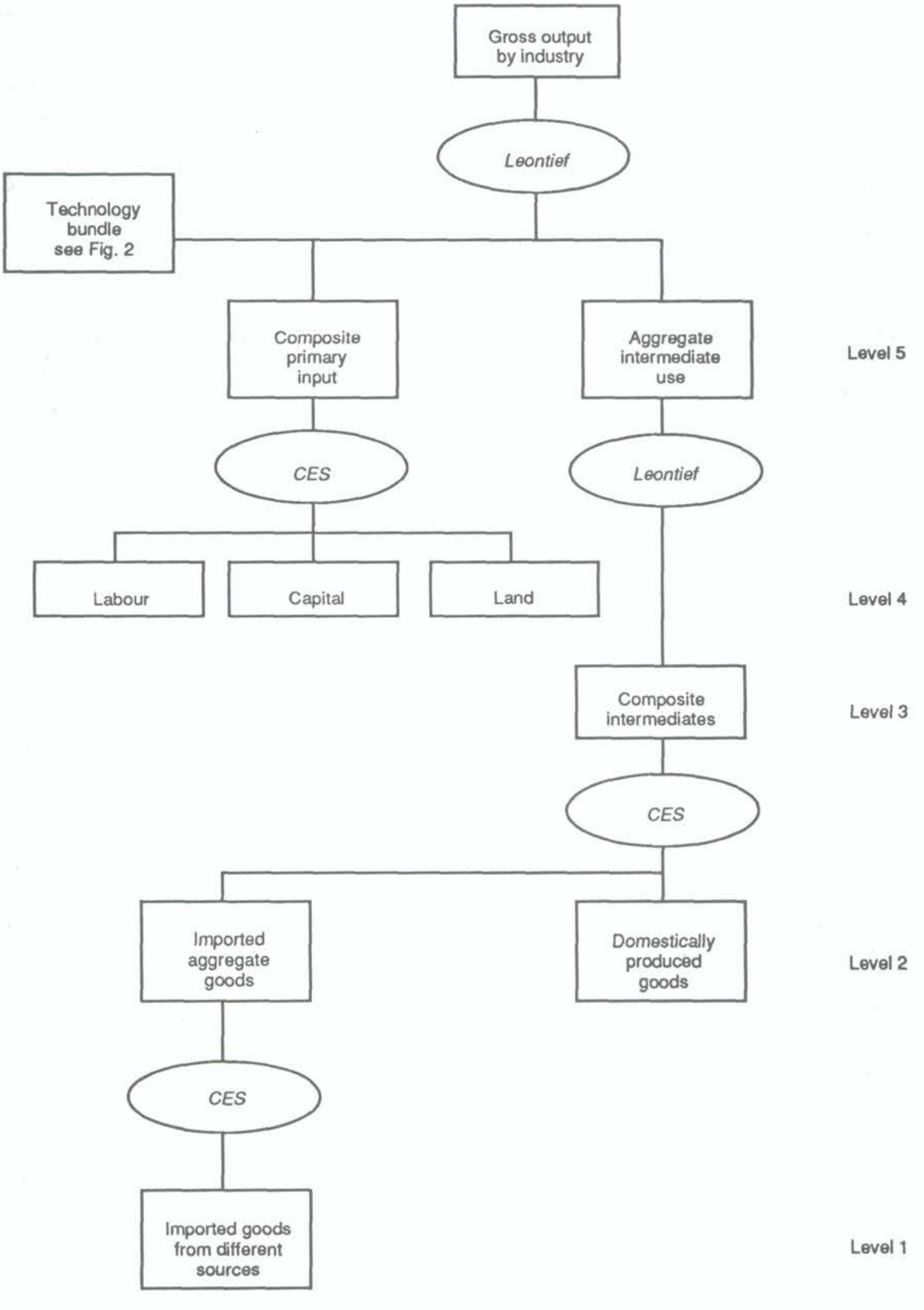

Fig. 1. MEGABARE production structure.

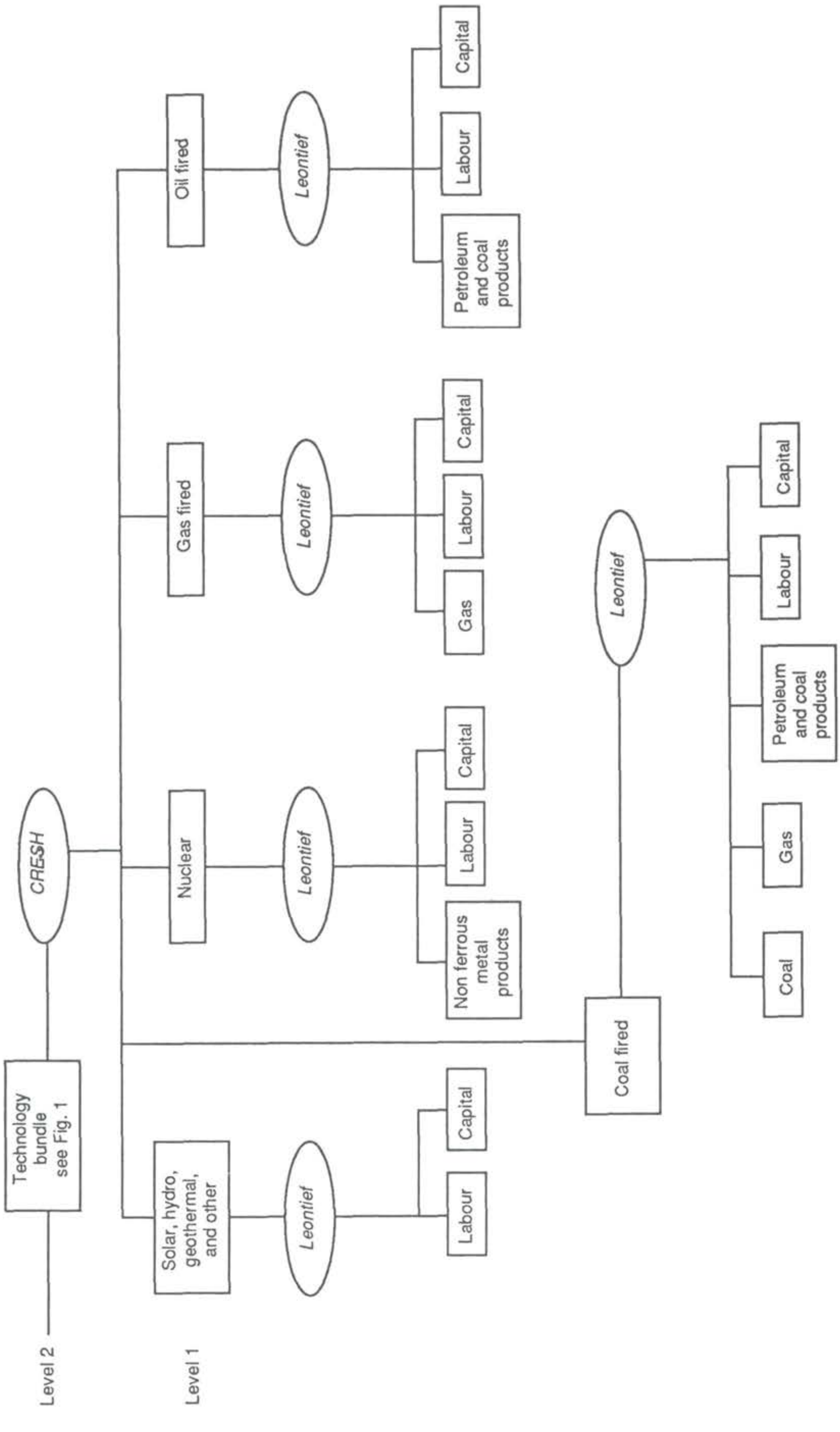

Fig. 2. Composition of technology bundle in the electricity industry.

Consumption

Each country/region is assumed to consist of a single "super household". This household disposes of the national income according to a Cobb-Douglas utility function over three forms of final demand: private household expenditure, government expenditure and savings. Therefore, the claims of each of these expenditures represent a constant share of national income. Government consumption expenditure is assumed to be allocated between commodities according to a Cobb-Douglas demand system. Hence the government consumption expenditure on each commodity is always a constant proportion of total government expenditure.

Private household consumption is assumed to be allocated between commodities according to a Constant Difference Elasticity (CDE) functional form. This functional form yields non-homothetic preferences and is readily calibrated from available estimates of income and own-price elasticities of demand. It is also assumed that, on the consumption side, the domestically produced and imported commodities are imperfect substitutes in the model following the standard Armington approach. Consumption of imports is further decomposed so that imported commodities from different sources are also assumed to be imperfect substitutes.

Investment

Global investment in the model is savings-driven. It is assumed that the "super household" in each country/region allocates income between current expenditures and savings based on a Cobb-Douglas utility function. Therefore, savings is a fixed share of each country's/region's income.

Government Sector

The government collects taxes from the "super household" in the form of income taxes and taxes on consumer purchases. In return, it redistributes income by distributing transfers to the household. *Ad valorem* taxes can be levied on purchases of commodities by producers and the government, and for investment purposes. In each country/region, government could also apply taxes on international trade such as destination specific export taxes and source specific import taxes on commodities.

Foreign Trade

The different countries/regions in the model are linked through commodity flows between each other which represent imports and exports. As indicated earlier, domestic and imported commodities are assumed to be imperfect substitutes for each other. Furthermore imported commodities from different sources are also assumed to be imperfect substitutes for each other. This assumption applies both to demands for intermediate inputs and to final demands.

Another global activity in the model is that of international transport services. These services are provided via a Cobb-Douglas production function that demands, as inputs, "services" exports from each country/region. In the model these "services" are represented by an industry called "trade and transport".

Environmental Measures

The model accounts for energy related carbon dioxide emissions in each region. Furthermore, the share of each country/region in global carbon dioxide emissions and the share of each type of fuel in the emissions of each country/region are also taken into account, especially in formulating emission accounting in the model.

The Benchmark Data Set

The initial equilibrium data set for the MEGABARE model is based on the SALTER database (Brown et al., 1993; Hambley, 1993). This database was built from basic input-output tables and fiscal information supplied by the different countries modelled or from secondary data sources. Bilateral trade flow data between countries are also used in the model. The reference time period chosen for the MEGABARE model is 1988 (based on the SALTER database).

Input-output data for OPEC were synthesised using the FIT programme (James and McDougall, 1993). Trade data for OPEC were collected for each of the 37 GTAP commodities. The input-output table for the Rest of the World region was reconciled to these trade values using the FIT programme and used as the input-output table for OPEC. A new Rest of the World region was created by subtracting the synthetic OPEC data from the original data for the rest of the world regions. It is possible that the OPEC input-output data may have inherited some features from the original Rest of the World that may not necessarily reflect OPEC.

The MEGABARE model is implemented using the GEMPACK suite of model development software (Harrison and Pearson, 1993). The model is represented in linearised form, but solved non-linearly using an Euler multistep procedure, as described in Pearson (1991).

A detailed description of the enhancements made in MEGABARE to the GTAP model is given in Appendix B.

4. Policy Experiments and Results

The MEGABARE model is used to carry out two policy experiments designed to provide a preliminary assessment of the potential trade and welfare effects of the proposed abatement policies. These policy experiments are:

- A 20% reduction in emissions in all Annex 1 countries. The instrument used to achieve this reduction in emissions was a carbon tax.
- A tradeable quota scheme among Annex 1 countries to achieve the same reduction in global emissions as the equal 20% reduction in emissions scheme. Annex 1 countries are also permitted to engage in joint implementation projects with non-Annex 1 countries.

The 20% reduction in emissions was chosen purely for illustrative purposes. In both experiments, the tax or quota operates at the point of consumption of the fossil fuel and is based on the carbon content of the fuel.

It is important to recognise that in the comparative static version of the MEGABARE model used in this study, changes in production, consumption and trade represent those which are likely to occur after a number of years of adjustment (medium term) when there has been sufficient time for the impacts of the policy changes to work through.

Equal 20% Reduction in Emissions in Annex 1 Countries

It is assumed that each region applies a carbon tax at the level required to produce a 20% reduction in emissions. It is further assumed that each region retains all the revenue from the carbon tax and this revenue is allocated between private household expenditure, government expenditure and savings in the same proportions that the "super household" disposes of national income.

As shown in Table 1, the estimated carbon tax required to bring about a uniform 20% reduction in carbon dioxide emissions in every country/region, varies widely between countries/regions. The level of the tax will reflect the relative costs at ruling input prices of substituting less carbon intensive for more carbon intensive energy sources and the costs of substituting non-energy for energy inputs.

The relative country rankings in terms of the tax accord well with prior expectations. The highest tax would be required in Japan. Fuel costs are high in Japan with its heavy dependence on imported fuels. Japan was severely affected by the oil price shocks of the 1970s and has made major efforts to economise on the use of energy. It would be expected that it would be costly for Japan to reduce its use of energy and there would be limited scope to substitute away from carbon intensive fuels.

Australia would be the second most heavily taxed country. Abundant supplies of low cost coal and relative paucity of other economic energy sources have resulted in more than 80% of electricity generated in Australia being drawn from coal fired stations. The relatively large primary metals processing sector in Australia

Table 1. Carbon tax required to achieve 20% reduction in emissions in Annex 1 countries

Country	Tax US$ per tonne of carbon
Australia	636
New Zealand	219
Canada	249
United States	219
Japan	739
European Union	261
ROW[a]	91

[a]The rest of the world aggregate contains the Annex 1 countries of the former Soviet Union and Eastern Europe. It was estimated that these regions were responsible for 65% of emissions from the Rest of the World. Thus, the tax was calculated to achieve a 0.65 x 0.20 = 0.13 reduction in emissions from the Rest of the World.

also means that Australia is an energy intensive economy. It would be expected that it would be relatively costly for Australia to reduce emissions.

There is not a great deal of difference in the level of the tax required for the European Union, Canada, the United States and New Zealand. These economies do not have the same dependence on high cost fuel imports as Japan. In the European Union and the United States no energy source has the same decisive cost advantage as coal in Australia and there are relatively good substitution possibilities. Canada is heavily involved in primary metals processing but has the advantage of being able to draw more than 60% of its electrical power from hydroelectricity.

The United States and New Zealand are the lowest taxed economies. In the United States there are good substitution possibilities among alternative energy sources and past policies of low energy prices have not encouraged a high level of energy conservation. New Zealand has the advantage of being able to draw on hydroelectricity for 70% of its requirements. According to the model, this proportion would increase if a carbon tax were imposed.

There appear to have been no previous studies using general equilibrium models on the relative rankings of carbon taxes for an equivalent group of regions. However, the relative country rankings of the level of carbon tax in the present study are in line with those obtained in Hinchy et al. (1993) where a partial equilibrium model was used. They are also in line with those obtained from the GREEN model to the extent that equivalent countries can be identified (Martin et al., 1992). However, the rankings differ significantly from those obtained from the WEDGE model (Industry Commission 1991, p. 112). The WEDGE results appear somewhat counter-intuitive, with the required carbon tax for the European Union being almost three times higher than that required for Australia and double that required for Japan.

The major structural difference between MEGABARE and WEDGE is in the treatment of inter-fuel substitution in the electricity industry as described above. It appears that the approach adopted in MEGABARE has significant effects and yields more plausible results.

The cost of reducing carbon dioxide emissions in each region in terms of three welfare measures is reported in Table 2. The three measures used are GDP (aggregate output), GNE (aggregate consumption) and a more sophisticated measure of consumer welfare based on the concept of equivalent variation (the change in income measured at base period prices required to leave the consumer as well off). The details of the measure used are given in Hertel and Tsigas (1993). Movements in the terms of trade are the major factor that may create differences between the output and consumption measures. If the terms of trade move against a country, although output may remain unchanged, a given volume of exports will buy less imports and domestic consumers will be worse off. The percentage change in the terms of trade is also shown in Table 2.

The extent of the decline in GDP roughly parallels the relative levels of the required carbon tax. However, there is a greater decline in real GDP in Australia than Japan even though a higher carbon tax was required in Japan. Such a result primarily reflects the greater dependence of the output structure in Australia on emission intensive products such as coal and non-ferrous metals and the poor medium term substitution possibilities. Thus, a given carbon tax forces a greater decline in output in Australia than Japan.

The contrast between Australia and Japan in terms of the consumption based measures is even more pronounced. Consumer welfare declines for Australia by 1.72% but only 0.64% in Japan. The main reason for this contrast is that the terms of trade for Australia decline by 1.12% but improve for Japan by 0.76%. The decline in the price of fossil fuels and derivative products damages Australia as an exporter but benefits Japan as an importer.

It is also apparent from Table 2 that all non-Annex 1 countries apart from OPEC suffer a reduction in real GDP even though only Annex 1 countries introduce a carbon tax. It is clear that there would be reduced demand from Annex 1 countries for fossil fuel exports from non-Annex I countries. More generally, a foreign trade multiplier would operate with reduced activity in Annex 1 countries resulting in reduced demand for exports from non-Annex 1 countries. The negative stimulus from Annex 1 countries in turn affects trade between non-Annex I countries.

The non-Annex 1 countries suffer even more (relatively) in terms of the consumption based measures. The reason is that the terms of trade deteriorate for all non-Annex 1 countries. Such a contrast is most pronounced for OPEC which suffers the second greatest decline in consumer welfare after Australia although it is the least adversely affected region in terms of the change in GDP. The reason for this difference is that due to OPEC's dependence on oil exports and the deterioration in the terms of trade, OPEC is

Table 2. Percentage change in welfare measures and the terms of trade resulting from 20% reduction in emissions in Annex 1 countries

Country	Percent change in real GDP	Percent change in real GNE	Percent change in consumer welfare	Percent change in terms of trade
Annex 1				
Australia	-0.93	-1.52	-1.72	-1.12
New Zealand	-0.13	-0.09	0.01	0.34
Canada	-0.26	-0.61	-0.50	-0.19
United States	-0.38	-0.36	-0.41	0.45
Japan	-0.49	-0.23	-0.64	0.76
European Union	-0.18	-0.23	-0.13	0.39
ROW[a]	-0.22	-0.46	-0.35	-0.26
Non-Annex 1				
China	-0.43	-0.82	-0.99	-0.69
OPEC	0.00	-0.66	-1.28	-3.93
ASEAN	-0.01	-0.51	-0.73	-0.96
Newly industrialising countries	-0.03	-0.32	-0.33	-0.25

[a]Percent change for combined Annex 1 and non-Annex 1 parts of Rest of World region.

forced to cut the volume of imports by 8.2% which is more than for any other region. OPEC is able to increase its exports of a range of products including non-ferrous metals where it is not penalised by a carbon tax. The real volume of production is maintained but there is a significant decline in domestic consumption due to the contraction in imports.

In spite of the decline in activity in non-Annex 1 countries, there is an overall slight increase in emissions from these countries due to changes in the composition of output. The decline in the price of fossil fuels provides a supply side incentive to increase emission intensive activities in non-Annex 1 countries. There is also a demand side stimulus with the increased costs of production of emission intensive products in Annex I countries creating increased demand for products from non-Annex 1 countries. Thus, electricity production rises in non-Annex 1 countries as do exports of non-ferrous metals and iron and steel.

In the literature, the concept of the emission leakage rate has been defined as the increase in emissions from non-cooperating countries divided by the reduction in emissions from cooperating countries. In the present simulation, the emission leakage rate is estimated to be 3.8%. Such an estimate probably underestimates the "true" leakage rate since the Rest of the World must be treated as an aggregate and it is assumed that no leakage occurs to the non-Annex 1 part of the Rest of the World.

The sectoral effects of the carbon tax for the world as a whole are presented in Table 3. As might be expected, coal production suffers the greatest decline. However, there is some increase in domestic production and imports of coal into non-Annex 1 countries in response to changes in the pattern of comparative advantage in emission intensive activities. Increased exports to China, ASEAN and the newly industrialising countries help moderate the decline in Australian coal production to 9%.

Natural gas emits somewhat less carbon dioxide per unit of thermal energy than coal. However, according to the model, at the carbon tax levels required to produce a 20% reduction in emissions, it is not economic to substitute from coal to natural gas to a significant degree. The substitution tends to be from coal to energy sources with high capital costs but zero emissions such as hydro, solar and nuclear power. Thus, production of natural gas declines. At lower tax rates, it would be economic to substitute natural gas for coal and natural gas production would increase.

Oil is the other primary fossil fuel identified and OPEC production declines by 7%. However, there is an increase in OPEC's comparative advantage in a number of emission intensive and other activities which, as noted above, moderates the decline in real GDP.

Table 3. Percentage change in world output under equal 20% reduction in Annex 1 countries

Sector	Percent change
Coal	-17.8
Oil	-9.2
Gas	-14.6
Other minerals	-0.8
Petroleum and coal products	-10.6
Chemicals, plastics and rubber	-1.2
Non-metallic mineral products	-0.6
Primary iron and steel	-0.3
Primary non-ferrous metals	-0.7
Fabricated metal products	-0.6
Electricity, gas and water	-2.2
Agriculture	0.2
Processed agricultural products	0.3
Investment goods	-0.4
Other manufacturing	-0.2
Services	-0.1

Electricity generation is the major source of carbon dioxide emissions in most countries. Unfortunately, in the present database electricity production cannot be separated from the distribution of gas and water. However, world output of the composite good declines by 2.2% with the greatest decline of 4.2% occurring in Australia. Such a result is consistent with Australia having the highest dependence on coal for electricity generation in the regions identified. According to the model, solar power becomes economic in Australia at the required tax rate and expands significantly. If a constraint were placed on the speed of introduction of such power, the impact of the tax on Australia would be much more severe.

Electricity production does not decline in all Annex 1 countries but is estimated to increase slightly in New Zealand and Canada. It will be recalled that these were the Annex I countries with the highest initial shares of hydroelectricity. There is some increase in electricity intensive activities in these countries that would be emission intensive activities in other Annex I countries. The best example is non-ferrous metals where a global relocation in activity occurs. Australian production of non-ferrous metals declines by 37%. Most of this decline would be attributed to alumina-aluminium, where electricity accounts for a major element in processing costs. Production of non-ferrous metals increases by 4% in both Canada and New Zealand and by 26% in ASEAN and 7% in the newly industrialising countries.

A Tradeable Quota Scheme in Annex 1 Countries with Joint Implementation

In the second experiment, it was assumed that a tradeable quota scheme operated in Annex 1 countries to achieve the same reduction in global carbon dioxide emissions as would be achieved by a 20% reduction in global emissions from Annex I countries. It was also assumed that Annex I countries could engage in joint implementation projects with non-Annex 1 countries.

If the maximum efficiency gains were extracted from joint implementation, the marginal costs of abatement would be equalised between Annex 1 and non-Annex 1 countries. Such a result is identical to that which would be achieved by operating a global tradeable quota scheme. In reality, without a formal market mechanism, it is unlikely that joint implementation would operate as efficiently as a tradeable quota scheme. Without price signals there would be a major information gathering burden on Annex I countries in identifying suitable projects for joint implementation in non-Annex 1 countries. Furthermore, there may be significant monitoring and verification costs associated with joint implementation. Nevertheless, a simple way of approximating a tradeable quota scheme in Annex 1 countries with joint implementation in non-Annex I countries is to model it as a global tradeable quota scheme. Such an approach was adopted. The results of such an analysis are subject to the qualification that they are likely to overstate the efficiency gains from joint implementation.

If non-Annex 1 countries are to be induced to participate in joint implementation, it seems reasonable to assume that they would insist that they be made no worse off than through non-participation. The outcome from non-participation is assumed to be that just modelled where all Annex I countries reduce emissions by 20%. Thus, it is assumed that non-Annex 1 countries would insist on a level of welfare at least equivalent to that in the previous simulation. If such an outcome is to be achieved, lump sum transfers of goods and services from Annex 1 to non-Annex 1 countries may be required.

In approximating joint implementation by a global tradeable quota scheme, the condition that non-Annex 1 countries are not made worse off is equivalent to a constraint on the way in which initial quotas can be allocated. Work is being undertaken to allow MEGABARE to be used in an optimising mode where the allocation of quotas that would satisfy a given welfare criteria can be determined. In the present application, a more ad hoc approach was used. A possible rule for allocating quotas that might make all countries better off would be to allocate quotas in proportion to initial emissions. Since marginal costs of abatement tend to be lower in non-Annex 1 countries, non-Annex 1 countries would undertake proportionately more emission reduction than Annex 1 countries. The proposed rule for allocating quotas would result in Annex 1 countries buying quotas from non-Annex 1 countries. Thus, non-Annex 1 countries would receive compensation for their greater contribution to reducing emissions.

It is important to note that the MEGABARE database includes a comprehensive range of tariffs, subsidies (including those on energy) and taxes for each country. Thus, a distorted world economy is modelled. From the theory of the second best, it is known that under some conditions, the introduction of what would be an efficient policy in a non-distorted economy could actually result in a reduction in welfare. Hence it is conceivable that tradeable quotas with joint implementation could actually result in a reduction in world welfare relative to an inefficient policy such as an equal 20% reduction in emissions in Annex 1 countries.

Table 4. Percentage change in welfare measures and the terms of trade resulting from a tradeable quota scheme in Annex 1 countries with joint implementation to achieve same reduction in global emissions as a 20% cut in emissions in Annex 1 countries

Country	Percent change in real GDP	Percent change in real GNE	Percent change in consumer welfare	Percent change in terms of trade
Annex 1				
Australia	-0.06	-0.23	-0.33	-0.22
New Zealand	-0.03	0.04	0.02	0.19
Canada	-0.05	-0.15	-0.17	-0.08
United States	-0.07	-0.12	-0.16	0.10
Japan	-0.01	0.07	0.02	0.33
European Union	-0.03	-0.04	-0.07	0.11
ROW[a]	-0.13	-0.35	-0.38	-0.31
Non-Annex 1				
China	1.40	6.42	9.48	3.77
OPEC	-0.02	-0.59	-0.98	-2.51
ASEAN	-0.10	-0.33	-0.52	-0.21
Newly industrialising countries	-0.07	-0.05	-0.08	0.08

[a]Percent change for combined Annex 1 and non-Annex 1 parts of Rest of World region.

The welfare measures under the proposed allocation are shown in Table 4 and can be compared with Table 2. In terms of real GDP, all Annex 1 countries would be significantly better off under the second simulation. The non-Annex 1 countries would be marginally worse off, apart from China, although the difference is extremely small. All countries would be better off in terms of the change in real GNE. All countries would also be better off under the consumer welfare measure, apart from the Rest of the World which is marginally worse off. It is clear that all regions could be made better off (the gainers clearly could compensate the losers) under the different welfare measures. Thus, the distortions in the world economy do not create second best difficulties at least for the simulations considered.

It is evident in comparing Table 4 and Table 2 that there is a greater improvement for the non-Annex 1 countries in the consumption based measures compared with the output measure. Such a result occurs in spite of adverse movements in the terms of trade for OPEC and ASEAN. The reason for this is that the sale of tradeable quotas allows non-Annex I countries to maintain a higher level of imports than could be sustained on the basis of their export volumes alone. Although nominally joint implementation is being modelled, the same principle would apply under tradeable quotas. To induce non-Annex 1 countries to participate in joint implementation, a lump sum transfer of goods from Annex 1 to non-Annex 1 would be required. Such a transfer in return for joint implementation has the potential to make both groups of countries better off.

The proposed allocation rule is not an optimal allocation rule under any of the three welfare measures. For example, it is rather more generous to China than would be required to induce China to participate in cooperative arrangements. Nevertheless, the results show that there would exist allocations not radically different from that proposed that would make all regions unambiguously better off under the three welfare measures.

There is a significant change in the pattern of global emission reduction under the two simulations as shown in Table 5. As noted above, a tradeable quotas scheme with joint implementation would result in marginal costs of abatement being equalised across emission sources. Since China undertakes a much greater cut in emissions than any other region it is evident that initially marginal costs of abatement in China are well below those in other regions. Annex 1 countries would have a strong incentive to seek joint implementation projects in China. The relatively low energy efficiency of China is well documented. The energy intensity of China in terms of thousand tonnes of oil equivalent per thousand dollars of GDP (in 1988 US dollars) is estimated at 1.7 whereas the comparable figure for OECD countries lies in the range 0.42 to 0.54 (International Energy Agency, 1994).

The change in the pattern of world output under a tradeable quota scheme with joint implementation is broadly similar to that under equal percentage reduction except that the changes are much smaller (Tables 6 and 3). Coal remains the most affected industry.

Australian production declines by 1.7% although exports fall by 5%. Domestic demand is much better maintained under what effectively amounts to a lower carbon tax.

There are several other differences between the simulation results that are worth noting. The relative decline in gas is less under the second simulation. Since the second simulation works like a much lower carbon tax than the first, there

Table 5. Pattern of global emission reduction under equal 20% reduction and tradeable quota scheme with joint implementation

Country	Equal 20% reduction	Tradeable quotas with joint implementation
Annex 1		
Australia	-20.0	-1.7
New Zealand	-20.0	-8.9
Canada	-20.0	-8.2
United States	-20.0	-6.7
Japan	-20.0	-2.5
European Union	-20.0	-6.4
ROW[a]	-13.0	-10.1
Non-Annex 1		
China	4.8	-48.2
OPEC	-0.3	-1.7
ASEAN	1.2	-6.9
Newly industrialising countries	1.4	-10.5
Global	-12.8	-12.8

[a]Percent change for combined Annex 1 and non-Annex 1 parts of Rest of World region.

Table 6. Percentage change in world output under a tradeable quota scheme with joint implementation

Sector	Percent change
Coal	-12.6
Oil	-4.8
Gas	-5.6
Other minerals	-0.6
Petroleum and coal products	-5.3
Chemicals, plastics and rubber	-0.5
Non-metallic mineral products	-0.6
Primary iron and steel	-1.6
Primary non-ferrous metals	-0.7
Fabricated metal products	-0.3
Electricity, gas and water	-1.2
Agriculture	0.7
Processed agricultural products	0.3
Investment goods	-0.1
Other manufacturing	0.0
Services	0.0

is positive substitution of gas for coal fired electricity generation in Australia and Japan and a much reduced shift away from gas in other Annex 1 countries. There is also increased use of gas for electricity generation in all non-Annex 1 countries.

It is also evident that the decline in world iron and steel production is greater than non-ferrous metals under the second simulation whereas the reverse was the case under the first simulation. Under the second simulation, a 63% decline in iron and steel production occurs in China whereas production is unchanged or increases slightly in all other countries. Imports of iron and steel production into China increase by 18%.

The global relocation of non-ferrous metals production that was a distinctive feature under the first simulation does not occur to the same degree under the second simulation. Production of non-ferrous metals in Australia declines by only 1% and there are only marginal changes in production in other Annex 1 countries. ASEAN was the region with the greatest growth in production under the first simulation but production declines by 28% under the second simulation. Production in China also declines by 32% under the second simulation.

5. Concluding Remarks

A number of results in the paper highlight how conclusions based on partial equilibrium analysis may be significantly modified in a general equilibrium framework with international trade. For example, on the basis of the level of a carbon tax required to achieve a given reduction in emissions, it might be thought that Japan would be more severely affected than Australia. However, the reverse appears likely to be the case in terms of the impact on domestic consumption given the relative movements in the terms of trade.

Under the Framework Convention on Climate Change the special circumstances of non-Annex I countries were recognised and less rigorous undertakings to reduce emissions were sought. However, according to the simulation results, non-Annex 1 countries would not be immune from unilateral action by Annex I countries to reduce emissions. All non-Annex 1 countries would suffer. A better outcome for both groups of regions could be obtained if agreement could be reached to engage in joint implementation projects.

The special difficulties of the fossil fuel exporting countries, Australia and OPEC, are also highlighted by the results. Given their abundance of fossil fuel, there are limited domestic medium to longer term substitution possibilities. Both regions face a significant loss in export volume and adverse movements in the terms of trade under action by other regions to limit carbon dioxide emissions.

An innovation in MEGABARE is the modelling of inter-fuel substitution in the electricity industry although the methodology can be extended to other industries. Such an approach appears to involve a significant gain in realism when comparison is made with the results from the WEDGE model. Further gains in realism are possible by obtaining more accurate data on the different technologies and the substitution possibilities and any constraints that may limit the use of different technologies in particular countries.

Work is also underway on developing an optimising mode for MEGABARE. Instead of having to run simulations to determine the welfare consequences of alternative policies settings, in the version of the model under development a welfare criteria can be specified and the policy setting that satisfies that criteria derived.

APPENDIX A

Sectors and Regions in the Current Version of the MEGABARE Model

Table A. 1. Concordance between 12 region and 18 region versions of MEGABARE

Aggregated region	Region
Australia	Australia
New Zealand	New Zealand
Canada	Canada
USA	USA
Japan	Japan
EC	EC
China	China
OPEC	OPEC
ASEAN	Indonesia
	Malaysia
	Philippines
	Thailand
Newly Industrialising Asian Countries	Korea
	Singapore
	Hong Kong
	Taiwan
OPEC	OPEC
Rest of World	Rest of World

Table A.2. Concordance between 16 sector and 37 sector versions of MEGABARE

Aggregated sector	Sector
Coal	Coal
Oil	Oil
Gas	Gas
Other minerals	Other minerals
Petroleum and coal products	Petroleum and coal products
Chemicals, plastics and rubber	Chemicals, plastics and rubber
Non-metallic mineral products	Non-metallic mineral products
Primary iron and steel	Primary iron and steel
Primary non-ferrous metals	Primary non-ferrous metals
Fabricated metal products	Fabricated metal products
Electricity, gas and water	Electricity, gas and water
Agriculture	Paddy rice
	Wheat
	Other grains
	Non-grain crops
	Wool
	Other livestock products
	Forestry
	Fishing
Processed agricultural products	Processed rice
	Meat products
	Milk products
	Other food products
	Beverages and tobacco
	Lumber and wood products
Investment goods	Transport equipment
	Other machinery and equipment
	Construction
Manufacturing	Textiles
	Wearing apparel
	Leather, fur and their products
	Pulp, paper and paper products
	Other manufacturing
Services	Trade and transport
	Other services—private
	Other services—government
	Ownership of dwellings

APPENDIX B
Description of MEGABARE

The MEGABARE model, and parts of it that constitute extensions to the underlying GTAP model, were described in section 3. The enhanced production structure of MEGABARE is illustrated in Fig. 1. In this appendix the equations corresponding to these extensions are described. As the MEGABARE model equations are implemented in a linearised form in GEMPACK, and the models solved non-linearly via this linearised representation as described in Pearson (1991), the equations will also be presented here in linearised form using GEMPACK notation. Thus the variables occurring in these equations are percentage deviations induced by the policy being simulated.

The solution of the cost minimisation problem subject to a CRESH production function, and the linearisation of the consequent input demand equations, is described in Dixon et al., 1982. Thus the demand for each technology used by an industry (only the electricity industry at present) is defined by

qtech(i,j,r) = *–atech(i,j,r) + qtb(j,r) – ESUBTB(i,j) [ptech(i,j,r) – atech(i,j,r) – ptb(j,r)]*

where

qtech(i,j,r)	=	percentage change in the output from technology *i* used in industry *j* in country *r*
ptech(i,j,r)	=	percentage change in the price of output produced by technology *i* used in industry *j* in country *r*
atech(i,j,r)	=	percentage change in productivity of technology *i* used in industry *j* in country *r* (technological change terms are included for future extensions and were set to zero for the simulations in this paper)
qtb(j,r)	=	percentage change in the output from the technology bundle used in industry *j* in country *r*
ptb(j,r)	=	percentage change in the price of the technology bundle used in industry *j* in country *r*
ESUBTB(i,j)	=	CRESH parameter for technology *i* used in industry *j*

Note that the CRESH parameters are uniform across countries. These parameters govern the degree of substitution of each technology for other technologies in the technology bundle. The Allen elasticity of substitution between technologies *i* and *k* in industry *j* in country *r* is

*ESUBTB(i,j) ESUBTB(k,j)/*sum *(l, TECH,STB(l, j,r) ESUBTB(l,j))*

where

the summation in the denominator is over the set of all technologies of industry *j* in country *r* and

STB(l,j,r)	=	share of technology *l* in the total value of the technology bundle in industry *j* in country *r*

For the simulations performed in this paper, all the CRESH parameters were set to five. Thus the CRESH specification is equivalent to a CES with all elasticities of substitution equal to five.

The percentage change in the price of a technology is a share weighted sum of the percentage changes in the prices of the inputs used in that technology. Thus

ptech(k,j,r) = sum *(i, TECH_COMM, stech(i,k,j, r) [pft (i,k,j,r) – aft(i,k,j,r)])*

where

the summation on the right hand side is over all commodities used in technology *k* in industry *j* in country *r* and

stech(i,k,j,r)	=	share of commodity *i* in total costs of inputs used in technology *k* in industry *j* in country *r*
pft(i,k,j,r)	=	percentage change in price of commodity *i* used in technology *k* in industry *j* in country *r*
aft(i,k,j,r)	=	percentage change in the efficiency of use of commodity *i* used in technology *k* in industry *j* in country *r*

The price of a commodity is constant between technologies, but provision is made in the equations to have this price differ. So

pft(i,k,j,r) = *pf(i,j,r) + slackpft(i,k,j,r)*

where

pf(i,j,r)	=	percentage change in the purchasers price of commodity *i* used in industry *j* in country *r*
slackpft(i,k,j,r)	=	difference in the percentage change in the price of commodity *i* when used in technology *k*

The primary use of this equation is when there is a capacity constraint on a technology and commodity *i* is capital. That is, the capacity constrained technology earns above normal returns to capital represented by *slackpft*. Capacity constraints were not enforced in either of the simulations presented in this paper.

For each commodity or primary factor used in a technology utilised by the electricity industry, the total use of that input by the industry is just the sum of the use in each technology, that is,

$qf(i,j,r) + af(i,j,r) = \text{sum}(k, TECH, SFT(i,k,j,r)\ [qft(i,k,j,r) + pft(i,k,j,r)]) - pf(i,j,r))$

where

$qf(i,j,r)$	=	percentage change in the demand for input i by industry j in country r
$af(i,j,r)$	=	percentage change in the productivity of use of input i by industry j in country r
$SFT(i,k,j,r)$	=	value share of technology k in usage of input i by industry j in country r

Note that the equation defining qf accounts for the possibility that pft differs from pf for some commodities.

The technology bundle is used in fixed proportions to industry output, and so

$$qtb(j,r) = -atb(j,r) + qo(j,r) - ao(j,r)$$

where

$atb(j,r)$	=	percentage change in the productivity of the technology bundle in industry j in country r
$qo(j,r)$	=	percentage change in the output of industry j in country r
$ao(j,r)$	=	percentage change in the productivity of industry j in country r

Carbon taxes are implemented in MEGABARE by incrementing the *ad valorem* taxes on fossil fuel use by magnitudes consistent with the amount of carbon dioxide emitted by the combustion of those fossil fuels. So

$$tfd(i,j,r) = invtfd(i,j,r)\ ctax\_scale(r)$$

where

$tfd(i,j,r)$	=	percentage change in the power of the *ad valorem* tax rate on domestically produced commodity i used by industry j in country r
$invtfd(i,j,r)$	=	the factor determining the appropriate magnitude of the *ad valorem* tax change (more fully described below)
$ctax\_scale(r)$	=	a scale factor

Similar taxes apply to private and government consumption of domestically produced fuels and to imported fuels. For simplicity of the equation structure, the taxes on imported fuels are specified as being levied at the border as import tariffs, rather than at the point of use. Thus

$$tms(i,r,s) = invtms(i,r,s)\ ctax\_scale(s)$$

where

$tms(i,r,s)$	=	percentage change in the power of the *ad valorem* tax rate on commodity i imported from country r to country s
$invtms(i,r,s)$	=	the factor determining the appropriate magnitude of the *ad valorem* tax change (more fully described below)

Where the use of an imported fuel does not involve combustion, as in the conversion of imported crude oil into petroleum products, a tax offsetting the import tariff is applied at the point of end use.

The function of the coefficients *invtfd, invtms* and *invtfs* is to ensure that the *ad valorem* taxes applied to fossil fuel combustion are consistent with a carbon tax which is proportional to the carbon dioxide released by combustion. The coefficients *invtfd, invtms* and *invtfs* are the ratio of the emission coefficients of each fuel divided by the purchase price. All prices are taken as unity initially, but are continuously changed throughout the model solution procedure in accord with the simulated price changes at each step of the solution procedure. The definition of these coefficients also incorporates a provision to exclude from taxation some uses of a fossil fuel. Formally

$$invtfd(i,j,r) = [1-impute(i,j)]\ [1-impute1\ (i,j)]\ emis\_coe(i)/L\_pfd(i,j,r)$$

where

$emis\_coe(i)$	=	emission coefficient of commodity i (is zero if commodity i is not coal, oil, gas or petroleum products)
$L\_pfd(i,j,r)$	=	price of commodity i used by industry j in country r
$impute(i,j)$	=	is zero or one depending on whether or not carbon dioxide is released by the use of commodity i in industry j
$impute1\ (i,j)$	=	is zero or one depending on whether or not it is desired to exclude commodity i used by industry j from taxation under the carbon tax

Similar definitions apply for *invtms* and *invtfs*. In the simulations performed for this paper, the matrix *impute*1 was used to exclude from taxation, or from quota restriction, all uses of fossil fuels by the fossil fuel producing industries. That is, the coal, oil, gas and petroleum and coal products industries did not have to pay for their usage of the commodities coal, oil, gas and petroleum and coal products.

Carbon tax revenue is calculated by summing the increments to commodity tax revenue due to changes in the commodity tax rates. The carbon tax rate in each country is then derived as the ratio of receipts from the carbon tax to emissions produced in the country. The equation determining the carbon tax rate is

L_emis(r) c_ctax(r) = ctaxrev(r);

where

L_emis(r)	=	emissions of carbon dioxide from country *r*
c_ctax(r)	=	change in carbon tax rate in country *r*
ctaxrev(r)	=	change in carbon tax revenue in country *r*

Emissions accounting for each country involves defining a measure of use for each fossil fuel and calculating the change in the contribution of that fuel to the country's emissions. Emissions from each country are then summed to determine global emissions.

[sum (s,REG, QXD(i,s,r)) + QD(i,r)] com_emis(i,r) = sum *(s, REG, QXD(i,s,r) qxs(i,s,r)) + QD(i,r) qds(i,r)*

emis(r) = sum *(i, TRAD_COMM, com_emis_shr(i,r) com_emis(i,r))*

L_globemis globemis = sum *(r, REG, L_emis(r) emis(r))*

where

the summations in the first and third equations are over all countries represented in the model, the summation in the second equation is over the sixteen tradeable commodities represented in the model, and

QXD(i,s,r)	=	quantity of commodity *i* from country *s* used in country *r*
QD(i,r)	=	quantity of commodity *i* produced and used in country *r*
qxs(i,s,r)	=	percentage change in the quantity of commodity *i* from country *s* used in country *r*
qds(i,r)	=	percentage change in the quantity of commodity *i* produced and used in country *r*
com_emis_shr(i,r)	=	proportion of the carbon dioxide emissions from country *r* produced by the combustion of commodity *i* (zero unless commodity *i* is coal, oil, gas or petroleum and coal products)
com_emis(i,r)	=	percentage change in the share of country *r* carbon dioxide emissions produced by the combustion of commodity *i*
emis(r)	=	percentage change in country *r* carbon dioxide emissions
L_globemis	=	global emissions of carbon dioxide
globemis	=	percentage change in global emissions of carbon dioxide

The coefficients *QXD* and *QD* are initially set to the dollar value of usage, and then updated at each step of the solution procedure according to the percentage changes in the quantities of usage *qxs* and *qds* respectively.

In this version of MEGABARE, in modelling tradeable quotas, advantage has been taken of the symmetry between a tradeable quota scheme and a uniform carbon tax across participating countries. The price of a quota per unit of emissions for a given volume of quotas would be identical to the uniform carbon tax per unit of emissions that would achieve the same reduction in global emissions. In the second simulation, it is required that quotas be allocated in proportion to emissions from each country. Such an allocation results in income transfers between countries that are identical to those that would result if the revenue from a given carbon tax was distributed among countries in proportion to their emissions.

Optionally constraining carbon taxes in each country to be equal is achieved through the addition of the equation

c_ctax(r) = glob_ctax + f_ctax(r)

where

glob_ctax	=	change in the uniform global carbon tax rate
f_ctax(r)	=	a slack variable for country *r* (explanation in next paragraph)

To simulate achieving an emissions reduction target in each country via carbon taxes, as in the first simulation presented in this paper, *f_ctax* and *globemis* are endogenised and *emis* and *glob_ctax* made exogenous. Endogenising *f_ctax* has the effect of removing the previous equation from the equation system to be solved. To simulate a uniform global carbon tax for reducing emissions, these four variables are exchanged in the closure. Then the previous equation becomes binding.

A tradeable quotas scheme, such as in the second policy experiment in this paper, is simulated as a uniform global carbon tax plus international income transfers which represent the effects of the initial allocation of quotas. Thus it is necessary to add equations to the model to facilitate this transfer. In the original GTAP model, a variable for allowing an exogenous income transfer to a country already exists. The equation for national income in country *r* is

National income = primary factor returns + tax revenue + income transfer

Denote the net income transfer to country *r* by *income_trans(r)*. There are two components involved in the income transfer in tradeable quotas simulations. First, the tax revenue from the uniform global carbon tax is confiscated from each country. Second, this revenue is then distributed to each country in proportion to some basis for initially allocating quotas. In the case of the second simulation, this basis was the initial value of emissions. Formally

income_trans(r) = *income_out(r)* + *income_in(r)*
income_out(r) = *ctaxrev(r)* + *f_income_out(r)*
income_in(r) = *basis(r) fl* + *f_income_in(r)*
sum(*r, REG, income_trans(r)*) = *globinc*

where

the summation is over all countries represented in the model and

income_out(r)	=	change in income taken from country *r*
income_in(r)	=	change in income given to country *r*
basis(r)	=	the basis for állocating quotas to country *r* (in the case of the second simulation, *basis(r)* would be equal to the initial emissions from country *r*)
fl	=	a scale factor ensuring all international income flows sum to zero
globinc	=	change in total net international income transfers (should always be zero)
f_income_out(r)	=	a slack variable
f_income_in(r)	=	a slack variable

The slack variable *f_income_out* is necessary to disable the international income transfer mechanism when it is not required, as in the first simulation. In this case, *income_out* and *fl* are exogenous and *f_income_out* and *globinc* are endogenous. The slack variable *f_income_in* allows the basis of allocating quotas to be overridden for some or all countries. Although this facility was not used in this paper, it is useful for determining endogenously initial allocations which satisfy certain criteria, such as ensuring equal percentage reductions in each country's GDP.

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Redistributive Impact of a Carbon Tax in Developing Countries

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We are still no closer to answers on whether the building up of "greenhouse" gases in the atmosphere could trigger a significant warming of the earth's surface. Nor do we know with any precision what the social and economic consequences of global warming might be. Yet countries all over the world are increasingly showing a willingness to act now, rather than wait for further scientific evidence. At the June 1992 "Earth Summit" in Rio de Janeiro, more than 150 countries signed a treaty aimed at stabilising greenhouse gases—mainly carbon dioxide (CO_2), which is by far the largest contributor to the greenhouse effect. A widely discussed potential measure to curtail carbon emissions is a tax on carbon content of fossil fuels levied by an international agreement or unilaterally. This paper examines the distributional implications of a national carbon tax in a developing economy.

The idea of imposing a national tax on carbon—the first tax ever to be aimed specifically at global warming—has found increasing favour of late, perhaps because governments would welcome a politically popular way of raising revenue. Such a tax would fall most heavily on the fossil fuel with the greatest carbon intensity per unit of energy. This would mean a relatively higher percentage price increase for coal than for alternate fuels (petroleum and natural gas), because coal not only has the highest carbon content per unit of energy but also the lowest price. For example, a $50/ton carbon tax in Western Europe would average increase end-user prices of coal by 35%, natural gas to households by 8%, and gasoline by 5%. This compares with price increases in the United States of 90% for coal, 13% for natural gas, and 12% for gasoline.

The carbon-cum-energy tax now being considered by the EC would start at $3/barrel of oil equivalency and increase by $1/barrel each year in real terms until it reached $10/barrel (roughly equivalent to a carbon tax of $70/ton) in the year 2000. Since the tax is supposed to be "fiscally neutral," governments would be expected to lower other taxes by a similar amount. But the chances of the EC adopting this tax anytime soon look poor, as the EC might well wait for others (the United States and Japan) to act, worrying about being at a "competitive disadvantage"—although to date no empirical work has been done to support such a fear.

The revenue potential of carbon taxes is extremely large. Indeed, a moderate $10/ton carbon tax, if imposed individually by all nations, could raise $55 billion just in the first year. For some countries (China), such revenues could amount for about 2% of GDP, enough to wipe out the central government's budgetary deficit. In countries were 1987 per capita GDP was less than $900, such a tax would yield revenues worth an average of more than 1% of GDP and 5.7% of government revenues. For the OECD countries, the numbers are lower, but still significant—0.21% of GDP and 1% of government revenues. Moreover, carbon taxes tend to be easier to administer in developing countries than personal and corporate taxes and thus less prone to tax avoidance and evasion.

The literature on industrialised countries typically portrays carbon taxes and other economic policy instruments such as GHG emissions taxes, gasoline or btu taxes as regressive, because outlays on fossil fuel consumption as a proportion of current annual income falls with income. But recent studies (see Table 1) using US and European data show that carbon taxes are considerably less regressive relative to lifetime income and annual consumption expenditures than to annual income, at least for industrial countries (see Poterba, 1991a; Jorgenson et al., 1992). Moreover, there is a reason to believe that the same holds true for the rest of the world, although for quite a different reason: In developing countries, institutional factors also play an important role.

Auguring for progressivity, or at least low regressivity in the developing world, are:

- If there is a significant degree of foreign direct investment from countries where

Table 1. A summary of empirical evidence on the redistributive impact of economic instruments

Instrument	Author	Country	Model	Results
Carbon tax	Bull-Hasset-Metcalf (1993)	United States	computable dynamic general equilibrium model; spending behaviour may adjust	tax burden is nearly proportional with respect to lifetime income
Carbon tax	DeWitt-Dowlarabadi-Kopp (1991)	United States	partial equilibrium model; spending behaviour may adjust; expenditure data; no recycling of tax revenues	distributional impact is regressive and varies across regions
Carbon tax	Jorgenson-Slesnick-Wilcoxen (1992)	United States	computable general equilibrium model; three stages intertemporal optimisation for household consumption	carbon tax is either mildly progressive or regressive depending on the welfare function used
Carbon tax	Poterba (1991a)	United States	partial equilibrium model; expenditure and income data	carbon tax is regressive, but the impact is smaller if expenditure data are used
Carbon tax	Schillo et al. (1992)	United States	DECO aggregate macro-economic model; expenditure data; three compensation systems	depending on the compensation system adopted, the carbon tax is regressive to neutral
Carbon tax	Schillo et al. (1992)	United States	Urban institute's TRIM2 microsimulation model; two compensation systems	carbon tax is regressive w.r.t. pre-tax income in both scenarios, but it becomes regressive to neutral relative to post-tax income
Carbon tax	Pearson (1992)	Europe	partial equilibrium model; spending behaviour may/may not adjust (2 models); Eurostat data	both models indicate that tax on domestic fuel is regressive, while tax on motor fuel is mildly progressive
Carbon tax	Pearson-Smith (1991)	Europe	IFS model of consumer expenditures; compensation system; spending behaviour may adjust	Ireland and UK show a regressive impact. For other countries, the burden is weakly related to income
Carbon tax	Shah-Larsen (1992)	Pakistan	partial equilibrium model; income and expenditure data; three scenarios	carbon tax incidence is either proportional or progressive in a developing country context
BTU tax	Bull-Hassett-Metcalf (1993)	United States	computable dynamic general equilibrium model; spending behaviour may adjust	tax burden is nearly proportional with respect to lifetime income
Gasoline tax	Greening-Schipper-Jeng (1993)	United States	partial equilibrium model; expenditure data	gasoline tax affects negatively mainly older married couples with dependent children. Income distributional results not reported
Gasoline tax	Krupnick-Walls-Hood (1993)	United States	partial equilibrium econometric model; limited adjusting behaviour	gasoline taxes are regressive much more than previous studies since income data are used
Gasoline tax	Poterba (1990)	United States	partial equilibrium model; expenditure data	gasoline tax is broadly regressive if we ignore the lowest income class. The latter class devotes a smaller share of their budget to gasoline than the lower-middle income class
Tax on GHG emissions	International Energy Agency (1993)	Europe	partial equilibrium model expenditure data	regressive effect on households if no compensatory measures with respect to domestic heating. Less clear result for motor fuels
Tax on direct fuel expenditure	Smith (1992a, 1992b)	Europe	partial equilibrium model; expenditure data; spending behaviour may/may not adjust; two compensatory systems	carbon tax is regressive, but if spending behaviour adjusts its impact is smaller; only lump sum transfers make the impact progressive
Tax on industrial energy use	Smith (1992a)	United Kingdom	input-output tables + consumer spending simulation programme	modest effect of changes in prices on consumers spending, but negative especially for low-income households

investors are allowed foreign tax credits against domestic liabilities, then a significant tax burden could be passed on to foreign treasuries, producers, and consumers.

- If price controls apply, producers often cannot pass the tax on to consumers in terms of higher prices.
- With binding import quotas or rationed foreign exchange, a tax would reduce the excess profits made by the privileged class.

Auguring for regressivity would be factors such as full market power. In this situation, the producer could increase product prices to fully pass on to consumers the carbon tax.

As it turns out, in most developing countries, there is some combination of the above elements, creating a situation where taxes can only be partially shifted to consumers. This means that a carbon tax would either be progressive or much less regressive than most people believe (see Table 2). Further, it is likely to be regressive only for the lowest income groups, which could be protected through direct subsidies or alternative measures. In addition, the overall tax structure could be made even less regressive by using the carbon tax to reduce personal income taxes (the latter are not necessarily progressive because of high tax evasion and urban-rural migration).

The above arguments are empirically examined in the following paragraphs using data for Pakistan.

Case (a): *Full Forward Shifting:* The degree of tax shifting depends upon the relative elasticities of supply and demand of the taxed commodity. For example, carbon taxes on production or use of fossil fuels could be fully forward shifted in the short run if the firms in the industry have full market power or the demand for the taxed commodity is perfectly inelastic or the supply is perfectly elastic. Table 3 columns (a) and (b) present carbon tax (\$10/ton) incidence calculations for Pakistan using data from the 1984/85 Household Income and Expenditure Survey and employing two alternative concepts of household income. Column (a) relates carbon tax payments to household current income by income class and column (b) to household expenditure by income class. Under both the alternative concepts of ability to pay, carbon tax burden falls with income and thereby yielding a regressive pattern of incidence. Such regressivity is nevertheless less pronounced with respect to household expenditures thereby confirming the same conclusion reached by Poterba (1991b) for the US.

Case (b): *Complete Absence of Forward Shifting:* The burden for carbon taxes could fall entirely on capital owners under a variety of circumstances. This could happen if price controls apply and legal pass-forward of the tax is

Table 2. Carbon tax incidence in developing countries

Institutional considerations	Implications for tax shifting	Tax incidence with respect to: Income	Expenditure	Lifetime income
a. Foreign ownership and control	Borne by foreign treasury through foreign tax credits	Nil	Nil	Nil
b. Full market power	Full forward shifting (100% on final consumption)	Regressive (pro-rich)	Less regressive	Less regressive
Perfectly inelastic demand for perfectly elastic supply				
c. Price controls and legal pass-forward of the tax disallowed	Zero forward shifting (100% on capital income)	Progressive (pro-poor)	Progressive	Progressive
Completely inelastic supply				
Import quotas and rationed foreign exchange	Reduced rents No effect on prices (100% on capital income)	Progressive (pro-poor)	Progressive	Progressive
d. An intermediate case of (a) and (b) above	Partial forward shifting (31% to capital income, 69% to final consumption)	Proportional	Progressive	Progressive

Table 3. Carbon tax incidence in Pakistan (carbon taxes (TAX) as percent of monthly income (Y) or expenditure (EXP))

	Full forward shifting		Capital owners		Capital owners (0.69)	Consumption (0.31)
Monthly income (Rupees)	TAX/Y (a)	TAX/EXP (b)	TAX/Y (c)	TAX/EXP (d)	TAX/Y (e)	TAX/EXP (f)
-600	1.49	1.19	0.66	0.53	0.92	0.74
601–700	0.89	0.83	0.62	0.58	0.71	0.66
701–800	0.91	0.86	0.64	0.60	0.72	0.68
801–1000	0.80	0.77	0.68	0.66	0.72	0.69
1001–1500	0.81	0.81	0.72	0.72	0.75	0.75
1501–2000	0.81	0.85	0.76	0.79	0.78	0.81
2001–2500	0.82	0.87	0.74	0.79	0.77	0.82
2501–3000	0.74	0.80	0.77	0.83	0.76	0.82
3001–3500	0.76	0.83	0.75	0.81	0.75	0.82
3501–4000	0.78	0.83	0.77	0.83	0.77	0.83
4001–4500	0.68	0.78	0.78	0.90	0.75	0.86
4500+	0.51	0.67	0.80	1.06	0.71	0.94
	Regressive	Regressive	Progressive	Progressive	Proportional	Progressive

disallowed or if the supply is completely inelastic to price. The carbon tax would then be fully borne by fixed factors of production. With binding import quotas or rationed foreign exchange, carbon taxes would reduce rents received by quota recipients rather than affect prices paid by consumers. Under the assumption of zero forward shifting, the burden of carbon tax is attributed to capital income alone. The allocation of tax by capital income is then related to household income and household expenditures. Both these calculations yield a progressive distribution of carbon tax burden (see columns (c) and (d)).

Case (c): *Partial Forward Shifting:* Both cases (a) and (b) are clearly polar cases and are unlikely to be fully satisfied for energy products in any country. There are only a handful of empirical studies which examine shifting assumptions empirically for developing countries. One such study was carried out for excise taxes in Pakistan by Jeetun (1978). He finds 31% forward shifting of excises in Pakistan. Given that a tax on carbon content of fossil fuels at production stage is by its very nature an excise tax, it would be reasonable to use this assumption for the distribution of carbon tax burden. In Table 3 columns (e) and (f), 31% of carbon tax is attributed to final consumption and 69% to capital income in general and then these series are related to household incomes and expenditures by income class. This results in a roughly proportional incidence of carbon taxes under the former series and a progressive incidence pattern under the latter series.

Comparison with Incidence of Personal and Corporate Income Taxes: The above analysis suggest that the regressivity of carbon taxes should be less of a concern in developing countries as compared to developed countries. This conclusion is further reinforced when one examines the incidence of personal income tax in a typical developing country. Personal income tax may not necessarily turn out to be a progressive element in the overall tax system when one considers tax evasion and urban-rural migration effects—two commonly prevalent features in lower to middle income countries. Shah and Whalley (1991) argue that with tax evasion, if the bribe rate is high and tax compliance is low, the redistributive impact of the bribe system is likely to dominate the direct redistributive effects of income taxes. The relevant issue then is who receives the bribes. One scenario is that, through a seniority system in public service, high officials with higher income and wealth receive a large portion (of the majority) of the bribe, along with professionals (accountants) who often act as "middlemen" in this process. Increasing the income tax can thus trigger a reverse distributional process from middle class businessmen and others to wealthy elites, an entirely opposite conclusion to the one commonly perceived. Thus tax evasion either reduces or offsets the progressivity of the tax system. The perceived progressivity of personal income tax is further clouded by the operation of the Harris-Todaro effect. In developing countries personal income tax is imposed on urban sector incomes only. Under such circumstances, if expected wages are equalised across modern and traditional sectors through rural-urban migration effects, some of the burden of the (urban) tax is shifted to the rural sector through intersectoral wage effects. Thus part of the burden of the tax is borne by rural workers through reduced wages although they face no legal liability to pay the tax. Potential importance of this effect is illustrated by Shah and Whalley (1991) using data for Pakistan for 1984–85. They find that incorporation of the Harris-Todaro effect in incidence calculations clouds the progressivity of the personal income tax in Pakistan. Shah and Whalley (1991) also present calculations for corporate income taxes that take into account complications introduced by foreign and public ownership of the corporate sector in Pakistan and find it a progressive tax.

The above analysis suggests that concerns over the regressivity of carbon taxes may be overstated. If the lowest income group is protected from the regressive impact of carbon taxes by direct subsidies or alternate measures, then the regressivity of carbon taxes may not pose a serious policy concern. Further if carbon taxes are used to reduce personal income taxes, traditional concerns that such a tax change would represent a move to a less progressive tax structure are not fully justified. Thus a commonly perceived and accepted case against carbon taxes on equity grounds does not hold water under a closer scrutiny.

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Intergenerational Equity and Discount Rates for Climate Change Analysis

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Abstract—Intergenerational equity is, in principle, an important issue for policies to address climate change as well as other environmental problems that have long time horizons. The procedure used to discount future benefits and costs can have a large effect on the evaluation of appropriate policies. Because of this large effect, it is important to consider carefully the assumptions and effects of the discounting procedure used.

This paper suggests that particularly for evaluations of major polices with long-term impacts it is most appropriate to consider discounting procedures based on use of the social rate of time preference with the shadow price of capital. This approach is well supported by a growing number of economists. It will tend to evaluate long-term environmental investments more favourably than discounting procedures based primarily on opportunity costs. However, the procedure explicitly and rigorously recognises the opportunity costs through the shadow price.

Importantly, the shadow price of capital approach is very sensitive to assumptions about such parameters as: the rate of social time preference; the rate of re-investment from returns to capital; the real return to capital; and the shares of both costs and benefits that are related to consumption and investment. This sensitivity suggests that the shadow price approach be complemented by analysis using simpler, more traditional discounting procedures, which can provide a check on the results of the more complex method.

Overall, use of this approach is suggested to provide a way of meaningfully evaluating long-term effects. In general, future benefits from climate change policies will not be discounted so much that they have no benefit, yet neither will the very real potential benefits of other productive investments be ignored. This approach, therefore, holds the potential for effectively considering the welfare of the current generation, while also recognising the welfare of future generations.

Intergenerational equity can be fundamental to policy choices surrounding climate change and other environmental problems with long-term impacts. In turn, discount rate policy for climate change analysis is important because the choice of the discount rate can have a major effect on the net present value estimated for alternative policies.

This paper considers the discount rate issue in the context of the climate change problem. The goal of this analysis is to review the state of discount rate policy and its relationship to equity considerations.

Issues surrounding equity, the discount rate, and their interaction are extensive. Section 1 of this paper, which follows, provides a brief discussion of some of these issues. Section 2 then considers in more detail the method which appears to have the strongest theoretical underpinning for discounting: the shadow price of capital approach. Implications of this approach and its sensitivity to assumptions are considered. Section 3 then suggests practical implications of the evidence on climate change and the discounting literature. Conclusions are suggested in Section 4.

1. Equity and Discounting

In order to consider the interrelationship between discount rate policy and intergenerational equity it is necessary to have an equity criterion. That is, it is necessary to define what we mean by intergenerational equity.

There are many conceivable formulations of such a criterion. Among the possibilities are:

- Sufficient resources are passed on to future generations to enable them to meet some minimal welfare criterion. This welfare level could be equal to the current level or some greater level, or it could even be below today's level but better than subsistence (e.g., a "safety net" type of approach).

- Less well-off generations are not required to sacrifice for more well-off generations.
- All future generations have equal opportunity to achieve the welfare level of all preceding generations.
- The process of reaching a future state is "fair". This fairness might be limited to voluntary market-oriented transactions (as in the framework suggested by Nozick (1974)), or it could be broadened to include political decisions (such as democratic decisions to provide public goods through taxation and regulation).
- Earlier generations assist future generations in a manner equal or proportionate to the degree they were helped by prior generations.
- Each generation's welfare is commensurate with their deservedness, defined in some way (e.g., the extent to which they abide by a moral code or promote future survival of the species).
- Future generations have the same opportunity to enjoy the environment as the current generation (see, e.g., Sen, 1982, p. 345).

These seven equity criteria may all have elements of reasonableness for certain applications, yet they can suggest very different long-run environmental policies and discount rate policies. They are listed roughly in order of increasing sensitivity to environmental concerns.

For example, the last criterion probably would provide the toughest barrier against considering tradeoffs between the environment and other goods. In contrast, the first criterion could allow future generations to be worse-off than today. Some of the criteria, such as the fifth, would tend to result in increasing economic opportunities over time, hence benefiting future generations. Others, such as the second, would not require this.

There are undoubtedly many other possibilities, some which may be found to have superior philosophical under-pinnings or popular support to criteria posited above. Finally, it may be that elements of more than one of these equity criteria may have to be met in order to reach a social consensus on equity. For example, both processes and outcomes may be important to people. A relatively non-interventionist criterion may be acceptable if it tends to lead to certain "moderate" outcomes, whereas it may be regarded as fatally flawed if it leads to certain "extreme" outcomes.

A key question in the case of climate change is the extent to which a policy based on efficiency-based benefit-cost analysis and discounting conflicts with any of the above criteria. For example, are climate change effects expected to be so large as to violate the last criterion? If so, and if this criterion is viewed as valid, then the problem may transcend choosing the right discount rate. Rather we would have a situation where a certain class of policy is infeasible (for political, ethical, or other reasons). Using a low, or even zero, discount rate is no guarantee that unacceptable future outcomes are avoided. Only specifying the policy, and working backward to solve for the discount rate would guarantee that the environmental constraint is not violated.

Nevertheless, there is wide agreement among economists that benefit-cost analysis and discounting are useful approaches for investigating policies that have intergenerational effects (e.g., Layard, 1976, p. 39; Cline, 1992, p. 243). In adopting this position it should be recognised that benefit-cost analysis is based on an efficiency criterion, maximisation of net benefits, and has limitations as a guide to policy. In particular, in order to make all parties better off when the efficient policy is chosen, winners must actually compensate losers.

Some of the concerns about intergenerational equity, though probably not all, may implicitly reflect concern that such compensation will not occur, and that future generations are not voluntarily consenting to the environmental quality that they are being allocated. For example, when compensation is possible in the form of investment now that makes the next generation better off—d'Arge et al. (1982, p. 255) find that the discount rate equals the market return to the productive investment under most of the equity criteria they consider. In fact, the only exceptions they identify are cases where the discount rate should be greater than the market rate.

For example, consider a "Rawlsian" social utility function, under which the objective is to maximise the welfare of the least well-off generation (Rawls, 1971); that is, for the case of a two generation model, max min $[U_1, E(U_2)]$, where U_1 is the utility of the present generation and $E(U_2)$ is the expected utility of the future generation. If the maximum possible utility of the present generation is below the expected utility in the future, a very high (in fact, infinite) discount rate would be implied by the ethical system, since transfers generally would not be made to the future in such a case.

Equality between the discount rate and return to investment is suggested by d'Arge et al. (1982) in the case of a utilitarian social welfare function (max $U_1 + E(U_2)$) and in a libertarian welfare function, which would maximise U_1 subject to $E(U_2) \geq U_2^0$, where U_2^0 is the level that would be attained in the future generation in the absence of consumption and investment by the present generation.

In contrast, when compensation cannot be made across generations, then the discount rates may be negative. This means that in some cases any benefit by the current generation at the expense of the future would decrease aggregate social welfare.

Full exploration of all the above equity criteria is beyond the scope of this paper. To proceed, therefore, it will be assumed that compensation across generations is feasible via consumption and investment decisions.

2. The Shadow Price of Capital

The approach recommended here for discounting looks at the value of consumption over time. Consumption benefits are discounted with the social rate of time preference, and it is this consumption that is assumed to be able to compensate parties who would otherwise be negatively affected by policies. Opportunity cost from foregone investments is explicitly considered through a shadow price that boosts costs. This shadow price can also boost certain types of benefits. This approach is based on the work of several researchers, including Feldstein (1976), Bradford (1975), Mendelsohn (1981), and Lind (1982).

Define B_t and C_t as the benefits and costs, respectively, in year t of a policy; i as the rate of time preference; S as the shadow price of capital; c as the fraction of costs drawn from consumption; w as the weight on capital costs, where $w = c + (1-c)S$; and z as the comparable weighted shadow price for benefits. The formula for the net present value of benefits in this case is:

$$NPV = \sum_{t=0}^{T} (zB_t - wC_t) / (1+i)^t$$

Where depreciation is geometric and a portion, σ, of the net returns from capital, ρ, is continually reinvested, the shadow price of capital can be written as:

$$S = (\rho - \sigma\rho) / (i - \sigma\rho)$$

A derivation of this formula is provided in the appendix.

Importantly, this approach is very flexible. The social rate of time preference can be based on individual decisions or, in principle, political decisions. Table 1 presents a range of estimates for the shadow price, S.

While the shadow price method uses a rate of time preference as the discount rate, it is possible to ask what standard discount rate gives equivalent results to the shadow price. For example, rather than doubling costs and using a low discount rate, one could generate a similar hurdle for a project by not adjusting costs and simply using a somewhat higher discount rate. Figures 1–4 illustrate the wide range of possible values for the discount rate implied by the shadow price of capital method. The analysis considers a project which has all of its costs at time zero and then yields a steady stream of benefits from year 1 until its termination. A range of assumptions are examined concerning: (1) the shadow price of capital; (2) the fraction of the public project's costs drawn from private investment; (3) the lifespan of the public project; and (4) the rate of time preference.[1]

Specifically, Figs 1 and 2 show that:

- As the fraction of costs drawn from investment increases, the equivalent discount rate also increases. This is because the shadow price receives a greater weight as the investment share increases.
- For shorter lifespan public investments the equivalent discount rate is greater than for longer lived investments. This is because weighting the investment's costs by the shadow price of capital requires greater increases in benefits for a short-term investment than a long-term one.
- Use of a higher rate of time preference (e.g., 4% instead of 2%) with the shadow price of capital method raises the calculated equivalent discount rate.

Figures 3 and 4 show the following:

- As the shadow price of capital increases, the equivalent discount rate increases. This is expected because a higher shadow price is a tougher hurdle for a project.
- Projects with larger fractions of costs drawn from investment or shorter lifespans imply higher equivalent discount rates, as in Figs 1 and 2.

Finally, the figures also demonstrate the reasonableness of the 7% discount rate which is the base case guidance of the Office of Management and Budget (OMB, 1992). This guidance is based in part on the economy-wide return to capital. In addition, it also can be consistent with the shadow price of capital approach under a variety of scenarios, as shown in the figures.

Importantly the calculations underlying Figs 1–4 assume that all benefits are in the form of

[1]The implicit discount rate is calculated as follows. First, the annual stream of benefits required to generate a net present value of zero under the shadow price of capital method is calculated, assuming an initial cost of 1 which is weighted by the appropriate shadow price of capital and investment fraction. Then the internal rate of return of this stream is calculated without weighting the initial cost by the shadow price of capital. This internal rate of return represents the discount rate that would cause the stream to have a net present value of zero; thus, it is the discount rate needed to generate the same decision as the shadow price of capital approach.

Table 1. The shadow price of capital under alternative assumptions

	Savings rate, from return net of depreciation								
	0			0.1			0.2		
	Rate of return, net of depreciation								
Rate of time preference	0.06	0.07	0.08	0.06	0.07	0.08	0.06	0.07	0.08
0.005	12.00	14.00	16.00	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
0.01	6.00	7.00	8.00	13.50	21.00	36.00	Infinite	Infinite	Infinite
0.015	4.00	4.67	5.33	6.00	7.88	10.29	16.00	56.00	Infinite
0.02	3.00	3.50	4.00	3.86	4.85	6.00	6.00	9.33	16.00
0.025	2.40	2.80	3.20	2.84	3.50	4.24	3.69	5.09	7.11
0.030	2.00	2.33	2.67	2.25	2.74	3.27	2.67	3.50	4.57
0.035	1.71	2.00	2.29	1.86	2.25	2.67	2.09	2.67	3.37
0.040	1.50	1.75	2.00	1.59	1.91	2.25	1.71	2.15	2.67
	Savings rate, from return net of depreciation								
	0.3			0.4			0.5		
	Rate of return, net of depreciation								
Rate of time preference	0.06	0.07	0.08	0.06	0.07	0.08	0.06	0.07	0.08
0.005	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
0.01	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
0.015	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
0.02	21.00	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite	Infinite
0.025	6.00	12.25	56.00	36.00	Infinite	Infinite	Infinite	Infinite	Infinite
0.030	3.50	5.44	9.33	6.00	21.00	Infinite	Infinite	Infinite	Infinite
0.035	2.47	3.50	5.09	3.27	6.00	16.00	6.00	Infinite	Infinite
0.040	1.91	2.58	3.50	2.25	3.50	6.00	3.00	7.00	Infinite

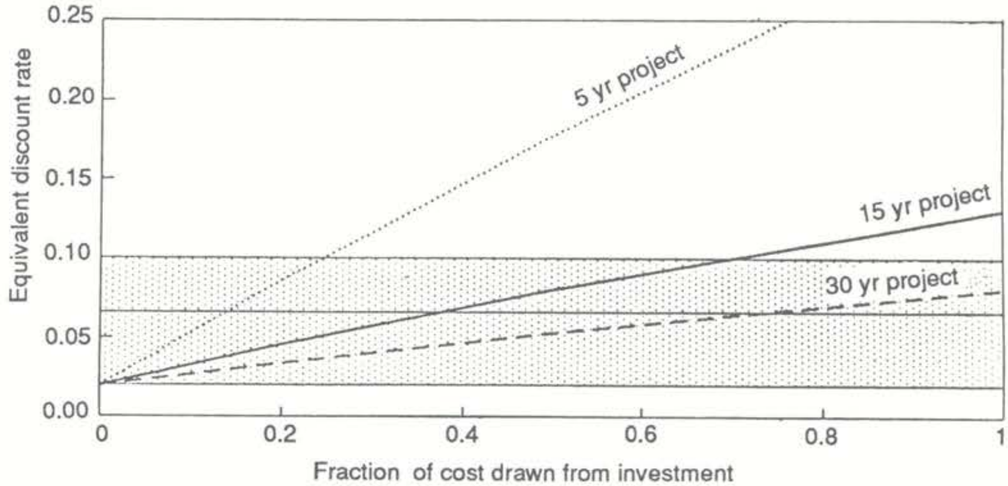

Fig. 1. Discount rate equivalent to the shadow price of capital approach with different fractions of costs from investment (shadow price of capital = 2, rate of time preference = 2%).

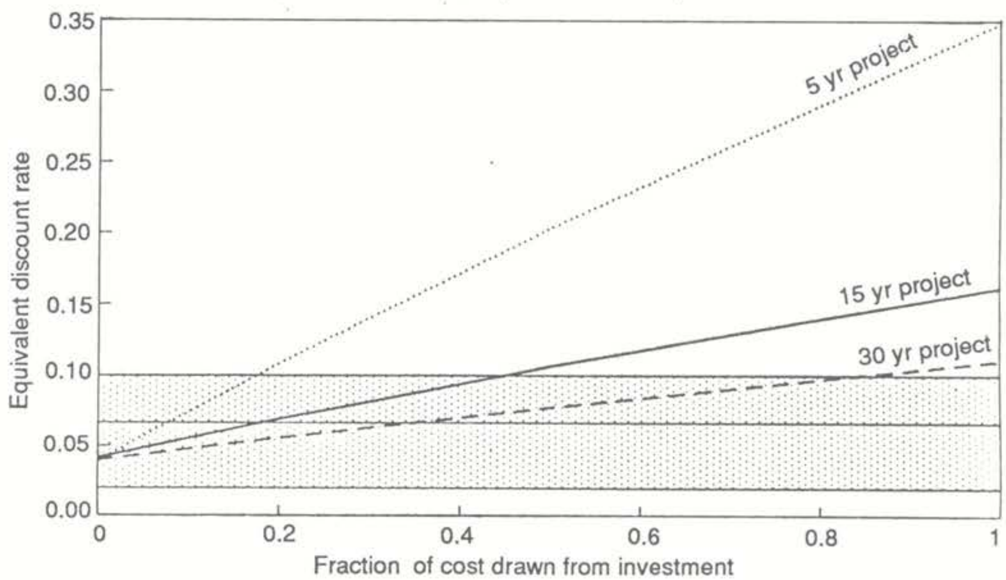

Fig. 2. Discount rate equivalent to the shadow price of capital approach with different fractions of costs from investment (shadow price of capital = 2, rate of time preference = 4%).

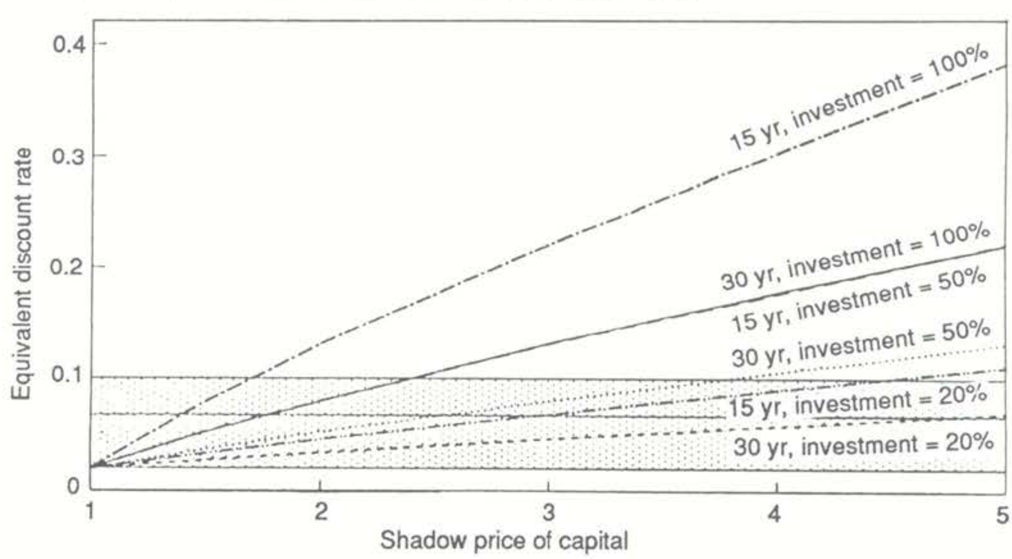

Fig. 3. Discount rate equivalent to the shadow price of capital approach under different shadow prices (rate of time preference = 2%).

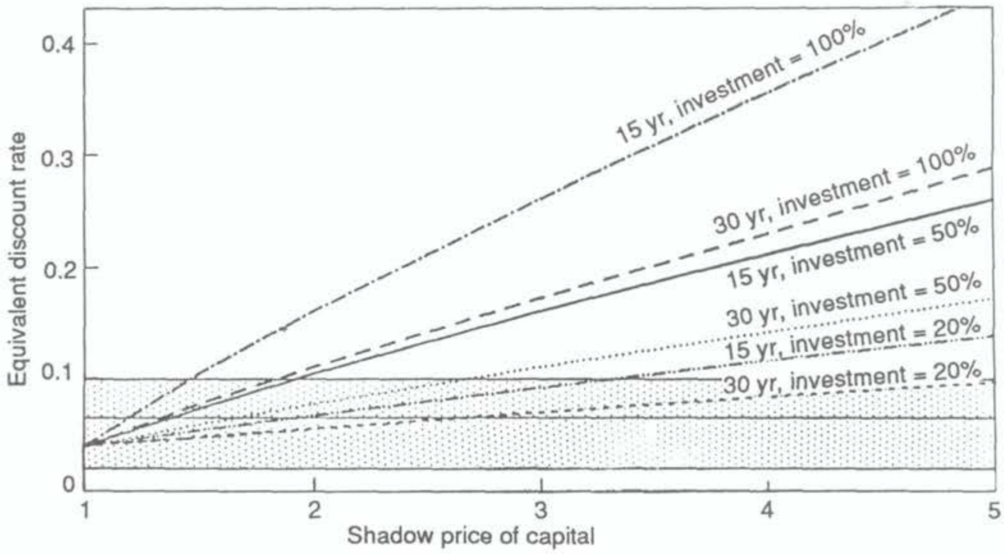

Fig. 4. Discount rate equivalent to the shadow price approach under different shadow prices (rate of time preference = 4%).

consumption. If the public policy under review also provides investment-type benefits, then the discount rate equivalent to the shadow price approach would be lower than shown here.

For example, consider a policy where the costs are incurred at time zero and the benefits then are received for the next 200 years. Suppose the rate of time preference is 2%, and that the shadow price of capital is 20. If benefits are all of the form of consumption, whereas 20% of costs are drawn from investment, then the project would require the equivalent of a 9.8% internal rate of return to provide net benefits under the shadow price method. That is, the high shadow price applied to costs dramatically offsets the favourable effect of using a low rate of time preference.

However, if 10% of the benefits are in the form of investment, which are also subject to the shadow price of 20, then the required rate of return on the policy falls markedly. In this case the rate of return would only need to be 3.4%. Moreover, if 20% of the benefits were in the form of investment (i.e., equal to the share for costs), then the required return would be only 2%, the rate of time preference assumed in this example.

In summary, therefore, the shadow price of capital is very sensitive to key assumptions and parameters, including:

Weights. The shares of benefits and costs from consumption and investment have a big effect on net present value. Cline (1992, p. 247) suggests that about 80% of costs and 90% of benefits of climate change policies will come from consumption. These estimates, however, appear quite rough. From the example above they can be seen to have important effects on the required return associated with the policy.

Social Rate of Time Preference. A range of possibilities is suggested by the literature. Sen (1982, pp. 327–28) summarises some of the vast literature debating whether private rates of time preference should equal public rates. Possible reasons for divergence include:

- The government may have a responsibility for future generations which transcends the preferences expressed by the present generation itself.
- Members of the current generation may value future generations more in their political decision-making than they express in their market activities.
- Members of the current generation may be willing to save in order to benefit future generations more if everybody commits to doing so, than they would do as individuals.

Because researchers differ on their justifications for the rate of time preference, estimates range from as low as 0.5% or 1%, to the expected real return on long term government debt (which is currently 3 to 4%, before personal income taxes), to even higher rates.[2]

In one recent and intriguing study, for instance, Cropper et al. (1992) surveyed three samples in the United States regarding time preferences for hypothetical policies that would save lives. The discount rates found there

[2] While the rate of time preference is typically assumed to be relatively low, many people may exhibit fairly high rates of time preference in their actual behaviour. Savings are concentrated in the upper end of the income distribution, and many people are net borrowers at high real interest rates. Thus, the private rate of time preference of the median voter or other representative individual may be rather high.

averaged about 18% for policies that would provide benefits in 10 years; in contrast, they averaged 3.4% for policies that would provide benefits 100 years out. In addition to suggesting that discount rates might not be constant for all time horizons considered, the study also found a great deal of variance across individuals' preferences. Some of this variation was explainable by demographic characteristics of the population surveyed.

Rate of Return to Displaced Investment. Based on data from the national income accounts on profits and interest and from the Federal Reserve System on assets, the average return to all forms of capital in the US between 1980–91 was close to 7%. A large portion of total capital is housing stock, which has a low return (about 4.3%). Corporate and non-corporate business capital had higher returns, along the lines of 7.7 and 9.4%, respectively. Assuming that marginal values are not very different from average returns, reasonable values for ρ, the return to displaced investment, would be on the order of 7% or more.[3]

Share of Returns Reinvested. The shadow price of capital is very sensitive to the assumption made about re-investment. If returns are continually reinvested, then displacement of capital will lead to a large long-term loss. Cline (1992, p. 246) rejects this assumption as leading to excessive values for capital investment. However, this is an empirical question which appears unresolved. The calculation of the shadow price here assumes that returns would be continually reinvested, and hence produces estimates of the shadow price that may ultimately be high.

Finally, note that all of the above parameters could, in principle, change over time.

3. Implications for Climate Change Analysis

A proper technical procedure for discounting very long term effects involves use of the shadow price of capital. The discount rate implicit in the shadow price of capital method may be relatively low. It will tend to be reduced by (1) selection of a low rate of social time preference and (2) an assumption that benefits have a significant investment component. If the investment component of benefits equals that of costs, then the shadow price falls out of the equation and one may simply discount with the rate of time preference. Generally, though, one would expect to see a larger share of costs coming from investment.[4]

A low social rate of time preference will tend to imply a high shadow price of capital. In theory, determining the rate of re-investment and the true loss to society by a one-time reduction in capital is a complex general equilibrium problem (Stiglitz, 1982). At present, though, even partial equilibrium calculations of the shadow price of capital are challenging.

The degree of damage caused by climate change can be very important to the evaluation of intergenerational equity.

- If the damage caused is relatively easily mitigated and does not involve major risks to life or ecosystems, then there may be insufficient reason to reject an efficiency-based analysis. This will be particularly the case if the future generation is compensated for the damage through a higher standard of living and capital stock than would otherwise arise. In this case there may be no conflict between rigorous, efficiency-based discounting procedures and considerations of intergenerational equity. If this scenario holds, then technological progress, economic growth, and social improvements may make future generations much better off than the current generation. In such a case, the argument for major adjustments in discounting procedures to favour future generations is more difficult to make on equity grounds.
- Alternatively, if the expected damage is severe, including major risks to human life, biodiversity, and large ecosystems, then this will probably imply different benefit estimates than appear to be the central case at present (see, e.g., IPCC, 1990; Nordhaus, 1990; and Beckerman and Malkin, 1994 for perspectives on potential impacts). The potential for compensation may also be diminished in such cases, however, and the adequacy of a policy that maximises discounted net benefits may be called into question on equity and other grounds. For example, those with Rawlsian or other egalitarian concepts of intergenerational equity are likely to object, as are those who believe in the merits of stewardship of our

[3]In addition, calculating the shadow price on the basis of a single weighted average return may understate the true opportunity costs (Lyon, 1990). In principle, the shadow prices of different foregone investments should be aggregated to produce a more accurate picture of costs.

[4]This would be the case if regulations mainly are directed at industry and have a significant incidence on capital. It could also be the case if the supply of capital is significantly affected by taxes on high-income persons (who do most of the saving) or by corporate income and other taxes. Alternatively, if policies are mainly implemented by consumption taxes or regulation of consumers, or if capital markets are characterised by a high degree of international mobility and little "crowding out", then the costs of policies may fall largely on consumption.

environment for species preservation or other biological or ethical reasons.

4. Conclusions

This paper suggests that the shadow price of capital approach to discounting is flexible enough to consider intergenerational policy issues. In pursuing this approach, however, analysts should give careful consideration to the parameters chosen, including the weights of costs and benefits drawn from consumption and investment; the social rate of time preference; the return to displaced capital; and the re-investment rate of returns to capital. A useful direction for research would be increased understanding of the incidence of alternative policies on investment and the cost of displacing the investment.

It is quite possible that with realistic assumptions the shadow price of capital will be very high. It should not be automatically assumed that modest values are intuitively correct. Particularly with low rates of time preference very high shadow prices are possible.

As a reality check on the results of the shadow price approach, it will also be useful for investigators to consider traditional discount rate studies. Opportunity costs of 7 to 8% may be adequate as an upper bound. This may be supplemented by consideration of lower discount rates, if opportunity costs are believed to be small, either due to the nature of capital markets (e.g., international mobility; see, e.g., Lind, 1990) or because the incidence of costs is directly upon consumption.

In addition, the extent of the degradation should be considered. Is it so severe that dollar magnitudes break down, and use of values for small changes in risks are unrepresentative? Or are the changes manageable enough so that the environmental impacts can be viewed as feasibly traded-off with other important goods, such as health care, food, education, or shelter?

An advantage of the approach discussed here is that it has the potential for increasing net social benefits relative to alternative approaches which assume very low discount rates in order to assist future generations. Such benefits can, in principle, make all parties better off. This could enable addressing of income distribution and other major needs within generations as well as addressing the intergenerational problems.

Importantly, though, results from this type of analysis should be considered in the context of the general limitations of benefit-cost analysis, including the question of whether losers are in fact being compensated by winners. If they are not, it is by no means clear that efficient policies make society better off.

Finally, while economists are sensitive to the likelihood of tradeoffs between efficiency and equity, it is not obvious that there is a major conflict between these objectives in the case of climate change. If future generations are substantially better off than current generations—because of continuing technological and social advances—then it is not clear that discount rates based on efficiency considerations should be reduced to provide an extra boost for future generations. At a minimum, exploring the implications of using rigorous, efficiency-based, discounting procedures is appropriate. Such procedures may ultimately benefit both current and future generations by highlighting the merits of all productive investments, including, but not limited to, environmental investments. These findings, together with information about equity and other intangibles, may then be used to better inform multi-objective policy decisions.

Disclaimer—This work is solely the responsibility of the author, and does not necessarily represent the position of the Office of Management and Budget or the US Government.

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APPENDIX

Derivation of the Shadow Price of Capital Under Geometric Depreciation

The shadow price of capital is the present value of the future consumption yielded by a unit of capital. Define S as the shadow price of capital; r as the gross rate of return from capital prior to depreciation; d as the rate of depreciation; s as the rate of savings from the gross return, r; C_t and K_t as the undiscounted consumption and capital stock in year t, respectively; and i as the rate of time preference.

Consider a unit of investment made in year 0. After one year this investment yields a gross return of r, allowing consumption C_1, equal to r $(1-s)$. The capital stock at this time, K_1, is $(1-d) + sr$. Similarly, in year 2 there is a gross return of $r(1-d+sr)$, and $C_2 = (r-sr)(1-d+sr)$ while $K_2 = (1-d+sr)(1-d) + [sr(1-d+sr)] = (1-d+sr)^2$. For year 3, comparable values are $C_3 = (r-sr)(1-d+sr)^2$ and $K_3 = (1-d+sr)^3$.

By induction the present value of consumption, S, can be expressed as:

$$S = \frac{(r-sr)}{(1+i)} + \frac{(r-sr)(1-d+sr)}{(1+i)^2} + \frac{(r-sr)(1-d+sr)^2}{(1+i)^3} + \ldots \quad (1)$$

$$= \frac{(r-sr)}{(1+i)}\left[1 + \frac{(1-d+sr)}{(1+i)} + \frac{(1-d+sr)^2}{(1+i)^2} + \ldots\right] \quad (2)$$

$$= \frac{(r-sr)}{(1+i)}\left[1 - \frac{(1-d+sr)}{(1+i)}\right]^{-1} \quad (3)$$

where $sr < i + d$ (otherwise S is infinite). The above expression simplifies to:

$$S = (r-sr)/(i+d-sr). \quad (4)$$

An analogous expression can be derived where it is assumed that funds are always set aside to cover depreciation of the original capital investment. In this case define ρ as the return net of depreciation and σ as the rate of saving from this net return. Therefore $\rho = r - d$ and $\sigma\rho = sr - d$. Substituting ρ and σ into the prior expression for S and simplifying yields:

$$S = (\rho - \sigma\rho)/(i - \sigma\rho). \quad (5)$$

Thus, expressions (4) and (5) are alternative ways of expressing the shadow price of capital in the presence of geometric depreciation. Equation (4) is used when the savings rate applies to the gross return, while equation (5) is used when the savings rate applies to the return net of depreciation.

Discussant's Comments

REINHARD LOSKE*

Talking about climate change and equity within countries, I see three ways to approach the issue:

- How does intra-national inequity contribute to climate change and environmental degradation?
- How is equity within countries affected in case of climate change becoming real?
- How is equity within countries affected in case of climate protection policies?

We heard excellent presentations of Sam Moyo and Mohammed Suliman on the question of how inequity contributes to environmental degradation.

We had very interesting presentations by Erik Haites and Isabelle Niang-Diop on how climate change affects a country or a certain sector of the economy.

The question of how preventive policies to save the earth's atmosphere affects equity within countries (e.g. distributional effects etc.) is subject of the next session.

This session has concentrated on equity aspects within countries in relation to a changing climate. As far as I am familiar with the literature, I would say that the research work on this specific question is not very intensive because there is so much speculation on the subject.

But having been invited to say a few words on the impact of climate change on equity within countries, I will base my statement on "common sense". I will distinguish between regional equity issues, social equity issues and economic equity issues.

Regional Equity Issues

The bigger a country is, the more relevant intra-national equity questions with respect to climate change would become, and vice versa. If a country is as small as Luxembourg, Monaco or San Marino, it will hardly make sense to elaborate on intra-national equity impacts on climate change. Except if it is a small island state like Bermuda: If there is no Bermuda any more because of a sea-level rise, there cannot be any intra-Bermudian equity any more.

The intra-national equity question may play a bigger role in large countries like the USA or Russia. It may well be that the mid-West of the USA will suffer more by droughts than New England; it may be that Florida will suffer more by sea-level rise than Oregon; it may be that Louisiana will suffer more intensified storms than Utah, and so on.

This issue is straightforward. If climate change is occurring, it will affect different regions in a different way. If these regions are within a nation state's border, it is a problem of intra-national equity. If they are not within the same border, it is a problem of inter-national equity. The scenario is not new.

But the unequal distribution of impacts may become politically relevant if a country—say Russia—would regard the expected negative impacts within its borders less relevant than the potential positive impacts of climate change. This would make inter-national negotiations even more difficult than they already are now.

Social Equity Issues

If one wants to speculate on the equity effects of climate change within countries, it seems to be justified to assume that poor people are affected more than rich people or the middle classes.

Yesterday, Atiq Rahman showed the difference between hurricanes in Bangladesh and the US. Though the intensity was comparable, many more people died in Bangladesh than in the US. I assume that people being victims of the Bangladesh hurricane did belong to the poor segment of the society. We can find a comparable situation in industrialised countries. When we had the incredibly cold winters during the last year in Europe and North America, some homeless people died. They simply did not have a place to stay. In Paris for example some clochards died because they were not allowed to stay in the metro stations overnight. The same would probably be true for climate change induced heat stress or the spread of diseases. Those who have the least will be affected worse. But again,

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this is not really new. It is just common sense. Maybe one could construct a theory of political uprise of the poor masses as a result of climate change. I would hesitate to do so.

Economic Equity Issues

Climate change will have different impacts on different sectors of a country's economy. In this context, I would like to quote the American economist William Nordhaus: He tells us to count before we leap. If temperatures rise, he says, skiing may suffer because of melting snow, but water skiing may gain because of more water. And he extends this sort of wisdom to the whole economy by asking: Which sector of the economy is most vulnerable to climate change? Of course, it is agriculture. What is the contribution of agriculture to the US GNP? Well it is below 5%. So even if the agricultural production would drop by 50%—he says—this would just reduce GNP by maybe 2%.

Such a position can only grow from the consciousness that it will always be possible to mobilise natural resources from somewhere else, from other parts of the world.

I doubt if a country whose agriculture accounts for 50 or more percent of the GNP can take such a position.

Finally, my point of view is that it is hardly possible to make a sound statement on intra-national equity impacts of climate change. If I still tried to do so, this is just because I did not want to question the wisdom of the organisers who set the agenda.

Discussant's Comments

ERIK HAITES*

The papers in this session raise two themes I would like to elaborate upon.

These themes are:

- The economic, as well as environmental, interdependence of the countries of the world; and
- Empirical measures of equity of economic impacts.

Climate change will have environmental consequences for all countries. The magnitude of climate change impacts on a particular country do not depend on the emissions of greenhouse gases by all countries.

The paper by Gunasekera illustrates the economic interdependence of countries. Trade and capital flows transmit economic impacts from one country to another. Thus, the mitigation costs borne by one country will have consequences for the other countries.

The OECD countries, due to their large share of total greenhouse gas emissions and high per capita incomes, are expected to bear the bulk of the cost of mitigating emissions. Gunasekera and his colleagues show that if these costs have a significant impact on consumption in OECD countries, economic growth in the rest of the world is also affected. This is the main message I took from Bradley's paper yesterday as well. It is not a surprising result—the oil price shocks of the 1970s confirmed the economic interdependence of developed and developing countries.

Given our economic interdependence, all countries have an interest in minimising the cost of addressing climate change. A mitigation strategy that imposes unnecessarily high costs on OECD countries imposes unnecessarily high economic costs for developing countries as well. All countries have an interest in minimising the cost of climate change.

All countries obviously have an interest in how the costs—damage and mitigation—are distributed. We have learned that there are numerous principles that can be used to judge the equity of the distribution of costs. But there is no preferred principle of equity for the distribution of the costs of climate change.

Economists have been criticised, rightly, for their lack of attention to equity relative to efficiency. Economists do, however, analyse the distribution of costs empirically. The papers by Shillo and Shah analyse the impacts of a carbon tax on different income groups.

It might be interesting to perform similar analyses of the distribution of climate change costs across countries. Empirical analyses of the impacts of a carbon tax on income groups within country raises issues such as the appropriate measure of income or expenditures. Those issues would become difficult for an empirical analysis of the distribution of climate change costs across countries.

Despite the difficulties, an empirical analysis of the distribution of climate change costs would provide useful insight into the magnitude of the equity issue. The Fischer paper on the impacts of climate change on agriculture suggests that developing countries will suffer larger damages than developed countries. This suggests that damage costs may be borne disproportionately by low income countries.

The expectation that developed countries will bear more of the mitigation costs affects, in part, the distribution of damages. However, the economic interdependence of countries means that the mitigation costs borne by developed countries also affect developing countries and it makes empirical analyses of the international distribution of climate change costs more complex. Nevertheless, I believe that such analysis would provide a useful context for further discussions of the international equity.

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Rapporteur's Report

JOSEPH H. KINUTHIA*

Thursday, 21 July 1994

Social and Cultural Aspects of Climate Change

In the recent past an increase in the frequency of occurrence of extreme climate events has been observed. This is considered as part of climate variations rather than climate change. Some of the extreme events which were highlighted include droughts and tropical cyclones. These extreme events could be indicators of climate change. If this is the case, the species will need to adapt to the new conditions or face extinction.

Within the last decade, droughts have become more intense and severe. This has caused the shrinking of lakes and rivers, and disruption of the social activities. Due to these droughts there has been ecological degradation and a shortage of resources which lead to the stiff competition between the users. As a result, in some countries, this has led to civil wars, poverty, migration and environmental degradation.

The problems of small islands and coastal areas were highlighted. These included coastal erosion due to sea level fluctuations and losses of life and property due to severe cyclones. The small islands, therefore, need to be compensated for hazards emanating from the global warming due to CO_2 emissions. However, such compensations will need the knowledge of the value of the islands and coastal areas which can only be achieved through insuring them against natural hazards.

From the foregoing, the habitats of the world are likely to suffer more from climate variability than climate change. Hence, future studies should emphasise more on climate variability than climate change.

Equity Within Countries

It was demonstrated that in addressing the greenhouse problem, a tradeable quota scheme is more efficient and equitable than an equal emission reduction scheme. Also, that non-Annex 1 countries would not be immune from unilateral action by Annex 1 countries to reduce emissions. And finally, a better outcome for both groups of countries could be achieved by engaging in joint implementation scheme.

On consideration of land entitlements tenure and climate change, it was noted that fears for environmental degradation, soil erosion, and deforestation should not compromise the rights of individuals. However, poor land distribution would lead to overutilisation of the meagre land and natural resources and a disturbance of land and biomass systems which affect climate change.

For proper management of the environment, an Indonesian case was presented. In this presentation it was suggested that National Committee on Climate Change should be open forums for discussions on national strategies to cope with the expected adverse effects. Hence, to gain and maintain popular awareness, it is important to develop research programmes and human resources through technology transfer, training and financial support.

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Equity and Social Considerations in International Agreements

Chair : Ruby Saha

Principles of Equity in International Environmental Agreements with Special Reference to the Climate Change Convention*

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Introduction

The United Nations Framework Convention on Climate Change (the Convention), signed by 155 States and the European Community at the 1992 United Nations Conference on Environment and Development (UNCED), entered into force on 21 March 1994.[2] For its Parties, the Convention establishes legally binding commitments to address, prevent and adapt to climate change to achieve the Convention's objective.[3] It also establishes an institutional framework to assess the effective implementation of these commitments as well as the elaboration of future commitments.[4] To achieve the Convention's objective, and to implement its provisions, the Conference of the Parties (COP) must be guided by, *inter alia*, the principles set out in Article 3 of the Convention. The first of these principles states:

> "The Parties should protect the climate system for the benefit of present and future generations of humankind, **on the basis of equity** and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof."(emphasis added).[5]

In addition the word "equitable" appears in the Convention in Article 4.2(a) concerning the developed country Parties' commitments and in Article 11.2 concerning the financial mechanism.[6] Article 4.2(a) provides in relevant part, that in deciding whether these Parties are "taking the lead", account must be taken of:

> "the differences in their starting point and approaches, economic structures and resource bases, the need to maintain strong and sustainable economic growth, available technologies and other individual circumstances, as well as the need for **equitable and appropriate contributions** by each of these Parties to the global effort regarding [the Convention's] objective."(emphasis added)[7]

Finally Article 11.2 provides that the Convention's financial mechanism:

> "shall have an equitable and balanced representation of all Parties within a transparent system of governance".

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[2]United Nations Conference on Environment and Development: Framework Convention on Climate Change, May 9, 1992, *reprinted in* 31 ILM 851 (hereinafter Climate Change Convention).

[3]For the full text of Article 2, see the Annex to this Paper.

[4]*Id.* at arts. 7–10.

[5]*Id.* at art. 3.1. The full text of Article 3 is set in the Annex to this Paper.

[6]*Id.* See Annex for full text of these provisions.

[7]*Id.*

The purpose of this Paper, prepared for the Intergovernmental Panel on Climate Change (IPCC) Nairobi Workshop on Equity and Social Considerations, is to examine the role of "equity", including "equitable principles", in international environmental legal agreements and cases concerning disagreements over rights and obligations concerning the allocation of natural resources, with a view to discussing their relevance to the implementation of existing obligations under the Convention as well as implications for the allocation of future responsibilities between States to protect the climate system.[8] The Paper will therefore focus on discussing the meaning and significance of "equity" and "equitable" in Articles 3 and 4.2(a) rather than in Article 11.2 where the term "equitable" clearly relates to concerns about fair participation and universal representation rather than allocation of natural resources.

As set out in the introduction in Part A below, it will become clear that, from an international legal perspective, the meaning of equity and equitable principles relevant for achieving an equitable result in a particular case cannot be generalised but depend on the context of each case. The examination of international environmental agreements and cases concerning disputes over access and use of natural resources in Part B of this Paper reviews how equity and equitable principles have been considered in other environmental contexts.[9] The role that equity and equitable principles might play in the determination of disputes about the rights and responsibilities of Parties to the Convention to protect the climate system will depend, to a large extent, on the interpretation, implementation, and future elaboration of the Climate Change Convention itself. Accordingly, Part C of this paper examines Articles 3 and Article 4.2(a) of the Convention and considers briefly what equity and equitable principles might mean in the specific context of the Convention. Part D attempts some conclusions and practical recommendations.

A. Equity and Equitable Principles

Nature of International Law

There is no universally agreed meaning of equity in international law. One legal scholar has characterised equity as "considerations of fairness, reasonableness, and policy often necessary for the sensible application of the more settled rules of law" which can comprise factual considerations and legal principles.[10] This Paper uses the term "equity" to refer to both elements. The term "equitable principles" is used to distinguish between equitable principles and factual circumstances relevant to reaching an equitable result.[11]

The legal notion of equity is created and applicable in the context of the international legal order which consists of principles and rules that are legally binding on States and other members of the international community in their interactions with each other.[12] States are the primary creators and subjects of international law. Other bodies such as international organisations, non-governmental organisations and individuals may also have rights, duties and obligations under international law.

A basic tenet of international law is the sovereign equality of all States.[13] All States have equal rights and obligations notwithstanding differences of an economic, political, social or other nature. Each State has jurisdiction over its territory.[14] Within its territory, a State has the right freely to choose and develop its political, social, economic and cultural systems. This includes the right to develop its own policies and laws regulating the exploitation of its natural resources.[15] As a corollary to these principles, each State has a duty to refrain from threatening

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[8] It is beyond the scope of this paper to analyse the relevance of international legal principles of equity on various regions, economic sectors, social groups or individuals within a State.

[9] See, Tom Franck and Dennis Sughrue, "Equity as Fairness". 81 *Geo L.J.* 563 (1993); Dan Tarlock, "Environmental Protection: The Potential Misfit Between Equity and Efficiency", 63 *U. Colo. L. Rev.* 871 (1992); Edith Brown-Weiss, "International Environmental Law: Contemporary Issues and the Emergence of a New World Order", 81 *Geo L.J.* 675 (1993); Cheng "Equity, Special Considerations and the Third World" 1 *CoJielp* 57 (1990); *See also*, Oscar Schachter, *Sharing the World's Resources*, Columbia University Press (1977) and Philippe Sands, *Principles of International Environmental Law*, Manchester University Press (forthcoming).

[10] Brownlie, *Principles of Public International Law* (Third Ed. 1979), New York, Oxford University Press, p. 27.

[11] For shorthand, factual circumstances will also be referred to as "equitable factors" or "equitable circumstances".

[12] It may be helpful to note the distinction between principles and rules. According to Ronald Dworkin, principles and rules: "point to particular decisions about legal obligations in particular circumstances, but they differ in the character of the direction they give. Rules are applicable in an all-or-nothing fashion...(A principle) states a reason that argues in one direction, but does not necessitate a particular decision...All that is meant, when we say that a particular principle is a principle of our law, is that the principle is one which officials must take into account, if it is relevant, as a consideration inclining in one way or another". Ronald Dworkin, *Taking Rights Seriously*, pp. 24–26 (1977) cited in Philippe Sands, *Principles of International Environmental Law*, Manchester University Press (forthcoming).

[13] Declaration on Principles of International Law Concerning Friendly Relations and Co-operation Among States in Accordance with the Charter of the United Nations.

[14] A State's territory includes the natural resources recognised as part of that territory. At present, a State has jurisdiction over its land, subsoil, all internal waters, the territorial sea, and the airspace immediately above all the foregoing. States have more limited sovereign rights (as opposed to full jurisdiction and sovereignty) in areas such as the 200 mile exclusive economic zone, and the continental shelf and its resources. Areas such as outer space, the high seas and deep sea bed, which fall outside the jurisdiction of any State, are considered global commons. Separate legal regimes define the rights and obligations States have in respect of these.

[15] *Id.*

the territorial integrity of another and the obligation not to intervene in matters within the domestic jurisdiction of any other State.[16]

States have the sovereign right to exploit their own natural resources pursuant to their own environmental and developmental policies subject to the proviso that they bear the responsibility of ensuring that activities within their jurisdiction do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.[17] This means that the question of how a State allocates responsibility for mitigating or adapting to climate change (*i.e.* how it allocates the costs and benefits of climate change), among various regions, economic sectors, social groups or individuals within its territory, is primarily a domestic matter. The following discussion focuses on the role of equity in relation to the allocation of responsibilities as between States and in particular, over disputes concerning access and use of natural resources.

Legal Nature of Equity

In its judgment on the 1982 *Continental Shelf case* (Tunisia/Libya), the International Court of Justice (ICJ), the principal judicial organ of the United Nations (UN), explained the nature of equity as follows:

> "Equity as a legal concept is a direct emanation of the idea of justice. The Court whose task is by definition to administer justice is bound to apply it."[18]

The Court went on to state that the application of equity in an international legal context differed from developments in some national legal system where equity was contrasted with the rigid rules of law which had to be mitigated in order to do justice.[19] The Court explained that "in general, this contrast has no parallel in the development of international law" and that "the legal concept of equity is a general principle directly applicable as law".[20] As a general principle of law, equity can therefore be a source of law, rather than merely consisting of considerations necessary for the sensible application of the law.[21]

The ICJ recognised in its 1982 Judgment that equity was relevant when the Court was called upon to apply international law and found that it could choose among several possible interpretations of the law.[22] In such cases, the Court was bound to choose the interpretation "which appears, in the light of the circumstances of the case to be closest to the requirements of justice".[23] However, even where equity was called upon to fulfil this function, the Court explained that equitable considerations had to lie within the law, and not be seen as something distinct and opposed to law. In its 1969 *Continental Shelf cases* (Germany/Denmark/Netherlands) Judgment, for example, the ICJ stated:

> "Whatever the legal reasoning of a court of justice, its decisions must by definition be just, and therefore in that sense equitable. Nevertheless, when mention is made of a court dispensing justice or declaring the law what is meant is that the decision finds its objective justification in considerations lying not outside but within the rules..."[24]

The specific mentions of considerations as being part of the general principles of law and of equitable considerations lying within the rules, are intended to distinguish the legal application of equity from a decision *ex aequo et bono*.[25] A decision *ex aequo et bono* "amounts to an avowed creation of new legal relations between the parties".[26] The ICJ is empowered by its statute to decide a case *ex aequo et bono*. As this would involve the Court in non-judicial functions such as conciliation, compromise and legislation, it may only exercise this power if clearly requested by Parties to a dispute.[27]

From the above, it is clear that in the absence of a specific request from State Parties to a dispute, equity must be applied as part of the

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[16] *Id.* In practice, natural resources do not always fall neatly within the territory or jurisdiction of one State. Accordingly, international law has evolved principles and rules to govern the access and use of such "shared natural resources".

[17] *See* Principle 2 of the Rio Declaration on Environment and Development, UN Doc. A/CONF.151/5/Rev.1 (1992), reprinted in 31 *ILM* 876. See Annex for full text of this Principle; *see also* Principle 21 of the Declaration of the UN Conference on the Human Environment in Report of the United Nations Conference on the Human Environment, UN Doc. A/CONF.48/14/Rev.1, UN Sales No.E.73.IIA.14(1973), *reprinted in* 11 *ILM* 1416.

[18] *Case Concerning the Continental Shelf (Tunisia/Libyan Arab Jamahiriya)*, 24 February 1982, *ICJ Rep.* 1982, p. 60, para. 71.

[19] *Id.* This restricted view of equity is still held by some legal scholars see e.g. Brownlie, *Principles of Public International Law* (Third Ed. 1979), New York, Oxford University Press, p. 27.

[20] *Case Concerning the Continental Shelf (Tunisia/ Libyan Arab Jamahiriya), ICJ Rep.* 1982, p. 60, para. 71. The sources of international law are set out in Article 38(1) of the ICJ's Statute, the full text of which is reproduced in the Annex.

[21] There have been many attempts to summarise the general principles of law. *See generally* Bin Cheng, *General Principles of Law as Applied by International Courts and Tribunals*, Cambridge, Grotius Publications Ltd. (1987).

[22] *Continental Shelf case (Tunisia/Libyan Arab Jamahiriya), ICJ Rep.* 1982; *See also* Article 38 of the ICJ statute, *supra* note 20.

[23] *Id.*

[24] *North Sea Continental Shelf Cases*, 20 February 1969, *ICJ Rep.* 1969. The judgment was adopted by 11 votes to 6. Several of the dissenting judges appended dissenting opinions on the application of equity and equitable principles to the cases.

[25] See Article 38.2 of the ICJ Statute produced in full in the Annex to this Paper.

[26] Hersch Lauterpacht, *The Development of International Law By The International Court of Justice* (1958) p. 213.

[27] The ICJ has never decided a case *ex aequo et bono* as parties to disputes are reluctant to give the Court such unbridled discretion.

general principles of law within the overall framework of the existing law governing a particular area of dispute. In applying equity, the Court cannot invent new principles or rules of law nor take into account equitable factors or considerations which lie outside the law. As the Court put it in its 1969 Judgment:

> "it is not a question of applying equity simply as a matter of abstract justice, but of applying a rule of law which itself requires the application of equitable principles, in accordance with the ideas that have always underlain the development of the legal regime..."[28]

From the above, a number of conclusions can be drawn from the Court's exposition of the legal nature of equity and its functions:

- Equity is part of the general principles of law; it is therefore itself a source of law to which the ICJ can turn when called upon to apply international law;[29]
- Unless Parties to a dispute clearly request it to exercise its power to decide a case *ex aequo et bono*, the Court cannot use equity to make new laws where no general principles of law (expressed in treaties or the actual practice of States) exist;
- Where several interpretations of the law are possible, equity requires that all relevant factors or circumstances should be taken into consideration. The relevant circumstances must be *legally* relevant in deciding a particular case rather than, for example, political circumstances which may or may not be legally relevant; whether a factor is legally relevant will depend on the particular characteristic of each dispute including the State practice involved;[30] and
- Finally, as equity functions within the context of particular legal regimes, the equitable principles and factors which are relevant for achieving an equitable result in a particular case cannot necessarily be generalised but depend on the legal and factual circumstances of each case.

The conclusion that in any particular case, equity consists of the application of equitable principles to achieve an equitable result taking into consideration all the relevant considerations may seem tautologous and rather unhelpful.[31] It does, however, signal an important point that may otherwise be overlooked: the application of equity relevant to one context cannot necessarily be transposed and applied to the climate change context to determine disputes about the equitable allocation of States' rights and responsibilities to protect the climate system.[32]

The following, by no means comprehensive, examination of equity in international environmental contexts provides some background information about the role of this concept in deciding questions concerning access to and use of natural resources in areas other than climate change. The legal insights and practical experience gained by States and the ICJ in dealing with equity and equitable principles in these different contexts provide valuable lessons for all those involved in implementing the Climate Change Convention and developing its provisions further.[33]

B. Examples of Equity in International Environmental Agreements and Cases

This section examines the role of equity in the context of international environmental agreements and cases concerning the following matters: the continental shelf; the deep sea bed; ozone depletion; international rivers; and biological diversity. It does not attempt to describe the law in each of these areas but aims instead, to point out the provision dealing with the following questions:

- What is the role of equitable principles in establishing entitlement to access and use of the natural resources in question (i.e. what is the legal basis on which any rights that can be claimed by a State and what is the nature of these rights); and
- What substantive factors or considerations are relevant in equitably apportioning (or delimiting) such rights between States to arrive at an equitable result.

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[28] In that case, the legal regime concerned the continental shelf. *See ICJ Rep.* 1969, p. 47, para. 85.

[29] For a non-exhaustive attempt at codifying the general *principles* of law, see Bin Cheng, *General Principles of International Law*, in particular, Appendix I of *General Principles of Law as Applied by International Courts and Tribunals, supra* note 20.

[30] See, for example, in the ICJ stated in the 1985 Libya/Malta Judgment "(i)n relation to continental shelf delimitation, although there may be no legal limit to the considerations which States may take into account of, this can hardly be true for a court applying equitable procedures. For a court, although there is assuredly no closed list of considerations, it is evident that only those that are pertinent to the institution of the continental shelf as it has developed within the law, and to the application of equitable principles to its delimitation will qualify for inclusion. Otherwise, the legal concept of continental shelf could itself be fundamentally changed by the introduction of consideration strange to its nature". 1985 *ICJ Rep.* 1985, p. 40, para. 48.

[31] Recognising this, the ICJ in its 1982 Judgment stated that whilst its terminology was generally used, it "is not entirely satisfactory because it employs the term equitable to characterise both the result to be achieved and the means to be applied to achieve this result". *ICJ Rep.* 1982, p. 59, para. 70.

[32] For one example of this see *Legal and Institutional Aspects of Joint Implementation under the UN Framework Convention on Climate Change*, Institute of Social Studies International Services, p. 57, 31 December 1993, the Netherlands.

[33] It is beyond the scope of this Paper to examine the role of equity and equitable principles by other international adjudicatory bodies and tribunals.

1. Continental Shelf

Perhaps the most developed body of international law dealing with the role of equity in determining the allocation of natural resources concerns the area of continental shelf. Developments in this area of international law began with the Proclamation of President Truman of the USA in September 1945 when the USA declared that the natural resources of the subsoil and seabed of the continental shelf—described "as an extension of the land-mass of the coastal nation and thus naturally appurtenant to it"—beneath the high seas but contiguous to its coasts was henceforth subject to USA jurisdiction and control.[34]

Other States followed suit establishing a considerable body of practice that was considered by the First United Nations Conference on the Law of the Sea and led to the adoption of the 1958 Geneva Convention on the Continental Shelf.[35] The development of the law continued with the incorporation of many provisions from the 1958 Convention into Part VI of the 1982 United Nations Convention on the Law of the Sea (UNCLOS) which will enter into force in November 1994.[36] Apart from the extensive provisions of treaty law, over the last twenty-five years the ICJ has given a number of significant judgments on the allocations of States' rights and responsibilities in disputes concerning the continental shelf.[37]

(a) Relevant Equitable Principles

These principles, stated by the ICJ in the North Sea Continental Shelf Cases and the Libya/Malta cases, include, *inter alia*:

- The principle of good faith negotiations which obliges parties to enter into negotiations with a view to arriving at an agreement.[38] This involves not insisting on their own position without contemplation of modifications as this would amount to merely going through the motions of a formal negotiations.[39]
- The principle to act in such a way that, in the particular case, and taking all the circumstances into account, equitable principles are applied.[40]
- The principle of not "refashioning geography or compensating for the inequalities of nature".[41]
- The principle of non-encroachment by one Party on areas appertaining to the other.[42]
- The principle that although all States are equal before the law and entitled to equal treatment "equity does not necessarily imply equality".[43]
- The principle that "there can be no question of distributive justice".[44]

In its judgments, the Court stated these principles to be of a general character and as such, applicable to delimitation, whether by adjudication or arbitration or through intergovernmental negotiations.[45]

In the North Sea Continental Shelf Cases, the ICJ made clear that its task in the dispute was to delimit but not apportion the areas in question "de novo" or afresh.[46] The Court rejected German arguments based on the doctrine of just and equitable share by stating that this doctrine was wholly at variance with the most fundamental of all the rules relating to the continental shelf, namely, that the rights of the coastal State in respect of the continental shelf are based on the natural prolongation of its land territory which as a matter of physical fact extends into the sea and which it is entitled to by virtue of its sovereignty over the land.[47]

Confirming this in its 1984 Judgment in the Gulf of Maine Case, the ICJ stated that "the judicial treatment of maritime delimitation does not involve the sharing-out of something held in undivided shares".[48] As the Court previously made clear in the 1985 Libyan/Malta dispute, entitlement to continental shelf is based on the concept of adjacency of coast to continental shelf.[49] The application of equitable principles

[34]For text of the Proclamation, see *Laws and Regulations on the Regime of the High Seas*, Vol.1, (1951). For a detailed commentary about the development of the legal regime of the continental shelf, see generally, *International Law*, Oppenheim, pp. 765–82, ninth edition, Longmans.

[35]For the text of relevant provisions from the 1958 Convention and UNCLOS see the Annex to this Paper.

[36]*Id.*

[37]The most important cases include: North Sea Continental Shelf Cases (1969); Case Concerning the Continental Shelf (Tunisia/Libyan Arab Jamahiriya) (1982); *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta)* (1985); *Gulf of Maine case (USA/Canada)* (1984); and *Jan Mayen (Denmark/Norway)* (1993).

[38]*North Sea Continental Shelf cases, ICJ Rep.* 1982, pp. 47–48, para. 85.

[39]This obligation is merely a special application of the general principle underlying all international relations, the pacific settlement of disputes, which is recognised in Article 33 of the Charter of the United Nations. *Id.* at paras 85–86.

[40]*Id.*

[41]*Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta), ICJ Rep.* 1985, p. 30, para. 46.

[42]*Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta), ICJ Rep.* 1985, pp. 29–31, paras 45–47.

[43]*Id.*

[44]*Id.* This appears to be of critical importance in the context of the Climate Change Convention.

[45]*Id.* at p. 30, para. 46.

[46]*North Sea Continental Shelf, ICJ Rep.* 1969, pp. 22–23, paras 18–20.

[47]*Id.*

[48]*Gulf of Maine* case, *ICJ Rep.* 1984, p. 32, para. 64.

[49]*Id.* at p. 32, para. 49.

cannot be used for "refashioning geography or compensating for the inequalities of nature...".[50] Other relevant equitable principles include, *inter alia*:

> "the principal of respect due to all such relevant circumstances; the principle that although all States are equal before the law and are entitled to equal treatment, equity does not necessarily imply equality...nor does it seek to make equal what nature has made unequal; and the principle that there can be no question of distributive justice."[51]

In the context of continental shelf delimitation, it is clear that wider, distributive notions of equity have not been successfully employed to develop an alternative legal basis for claiming entitlement to sovereign rights over areas of continental shelf and the natural resources to be found therein. This refusal by the Court to engage in broader, distributive notions of distributive justice can be contrasted with States' negotiations to determine entitlements to continental shelf that lie beyond the area of national jurisdiction.

These provisions, found in UNCLOS, are related to those concerning the designation of the regime of the deep sea bed as a "common heritage of mankind" under Part XI.[52] Article 82 of UNCLOS provides that in respect of exploitation of non-living resources, a coastal State, with a continental shelf extending 200 miles beyond the baseline of the territorial sea, shall make payments or contributions in kind to the Authority to be established under Part XI for distribution on the basis of "equitable sharing criteria", taking into account the interests and needs of developing states, particularly "the least developed and land-locked among them".[53]

Thus, in their legislative efforts, States have made extensive use of broad, distributive notions of equity that make a limited attempt to "make equal what nature has made unequal". Once UNCLOS is in force, it remains to be seen how the provisions concerning equitable sharing criteria and the common heritage of mankind will come into operation. Third-party settlement of disputes concerning the interpretation of UNCLOS' "equitable" provisions may provide useful clarification.

(b) Relevant Factors in Equitable Apportionment

As pointed out above, to distinguish the exercise of its powers from broader, distributive notions in the context of continental shelf, the Court speaks of delimitation of areas, rather than apportionment. The relevant rule of law is that delimitation between States with opposite or adjacent coasts must be effected by agreement on the basis of international law in order to achieve an equitable solution.[54] There is no closed list of considerations which the Court may take into account to arrive at an equitable solution, although these considerations must be "pertinent to the institution of the continental shelf as it has developed within the law".[55]

What factors has the Court looked at and what weight has it accorded to them? In the Jan Mayen case, for example, the Court considered the following factors:

(a) geographical context;
(b) proportionality;
(c) constitutional status of Jan Mayen;
(d) population;
(e) socio-economic considerations;
(f) cultural heritage;
(g) national security;
(h) conduct of the Parties; and
(i) other delimitations effected by them.[56]

The Court recognised that the island of Jan Mayen (belonging to Norway) only had a temporary population of 25 persons who occupied the island for the purpose of employment.[57] According to Danish claims, the facts that the island could not sustain human habitation or have an economic life of its own ought to have been taken into account when balancing the claims of Greenland, permanent population 55,000, whose economy was extensively dependent on fisheries. The Court rejected Denmark's argument stating that neither the limited nature of the population of Jan Mayen nor socio-economic factors were relevant circumstances to be taken into account.[58] It pointed out that the process of delimitation was based "solely on the possession by the territory concerned of a coastline".[59] A critical fact to note

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[50] *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta)*, *ICJ Rep.* 1985, p. 30, para. 46.

[51] *Id.*

[52] *United Nations Convention on the Law of the Sea* (UNCLOS), 10 December 1982, art. 135. UNCLOS is reprinted in 21 *ILM* 1261. For the text of the relevant provisions see Annex.

[53] *Id.* at art. 82.

[54] According to the ICJ, this rule, expressed in Article 83 UNCLOS reflects the requirements of customary law. see *Jan Mayen case*, *ICJ Rep.* 1993, at para. 48.

[55] *Jan Mayen case*, *ICJ Rep.* 1993, p. 29, para. 57.

[56] The *Jan Mayen* case was decided on the basis of Article 6 of the 1958 Geneva Convention on the Continental Shelf. See also *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta)*, where the Court is asked to consider many of the same factors.

[57] *Jan Mayen case*, *ICJ Rep.* 1993, p. 39, para. 79.

[58] *Id.* at pp. 39–40, para. 80.

[59] *Id.*

is that size or lack of a permanent population was therefore deemed irrelevant.

With regards to its refusal to recognise socio-economic factors as relevant, the Court followed its reasoning in the 1982 Tunisia/Libya Case and the 1985 Libya/Malta Judgment.[60] In the 1982 case, Tunisia stressed its economic and developmental needs arguing that for an equitable result it was entitled to a greater share of the shelf than the already oil-rich Libya.[61] The Court rejected these arguments stating that it could not take such factors into account because a country's economic wealth was subject to change.[62]

Similarly, in the 1985 case, the Court rejected Malta's arguments that delimitation should be influenced by the relative economic development of the two States, in particular, that account should be taken of Malta's lack of energy resources, its requirements as an island developing state and the range of its fisheries.[63] The Court stated:

> "It is clear that neither the rules determining the validity of legal entitlement to the continental shelf, nor those concerning delimitation between neighbouring countries, leave any room for any considerations of economic development of the States in question".[64]

One example where the Court has given an indication that socio-economic development might be relevant to achieving an equitable outcome is the 1984 *Gulf of Maine* case. In this case both the USA and Canada had stressed the importance of socio-economic factors on their respective fishing communities.[65] Whilst the Court rejected the relevance of these claims on the facts of the case before it, it did state that it might be equitable to take such factors into account where:

> "the overall result should appear radically inequitable as entailing disastrous repercussions on the subsistence and economic development of the populations concerned".[66]

On the relevance of security, in the Libya/Malta Judgment, the ICJ accepted that whilst considerations were "not unrelated to the concept of the continental shelf", they were not of particular significance in the case itself.[67] The same assessment was made in respect of security concerns expressed in the Jan Mayen case.[68]

What this body of law does make clear, however, is that the jurisprudence of the Court has not yet had to deal in great detail with disputes involving natural resources where it must consider interpreting rights and responsibilities that are themselves related to or conditional upon, the consideration of factors such as socio-economic development or the needs of the present population. Moreover the Court has been reluctant to use equity as a basis to engage in exercises involving distributive justice—which may be of critical concern in the area of regulating access and use of natural resources. It is also clear from the number of dissenting opinions attached to the Court's judgments on the continental shelf that a noteworthy body of legal opinion within the Court questions the underlying lawfulness of the Court decisions which place an overwhelming reliance on achieving an "equitable result" without clarifying what would amount to an inequitable result.[69]

These facts suggest that, in the absence of clear legal rules requiring the consideration of relevant socio-economic factors, or redistribution of natural resources, the ICJ may not necessarily regard them as relevant or of paramount importance in other disputes concerning rights and obligations relating to natural resources, such as the global atmosphere.

2. The Deep Sea Bed

The Third United Nations Conference on the Law of the Sea, extended from 1973–82, was called to address the emerging possibility of exploiting the mineral resources of the deep seabed extending beyond the area of the continental shelf and the national jurisdiction of a coastal State but quickly developed to address much broader concerns.[70] The long negotiations were set against the background of ever greater portions of sea being claimed by coastal states'

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[60] *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta)*, *ICJ Rep.* 1985.

[61] *Continental Shelf case*, *ICJ Rep.* 1982, p. 49, paras 77–78.

[62] The Court pointed out that "a country can be poor today and become rich tomorrow as a result of an event such as the discovery of a valuable economic resource". para. 77.

[63] *Id.* at pp. 30–32, paras 40–42.

[64] *Case Concerning the Continental Shelf (Libya/Malta)*, *ICJ Rep.* 1985, p. 33, para. 50.

[65] *Gulf of Maine case*, *ICJ Rep.* 1984, pp. 97–102, paras 230–41.

[66] *Id.*

[67] *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta)*, *ICJ Rep.* 1985, p. 33, para. 51.

[68] *Jan Mayen case*, *ICJ Rep.* 1993, p. 41, para. 82.

[69] It is argued for example, that this leaves the Court with too much discretion to determine distributive questions which properly lie outside its jurisdiction as none of the parties to the disputes concerned have asked it to exercise its powers to make decisions *ex aequo et bono*, for example, see the dissenting opinions of Judges Oda and Evenson in the *Case Concerning the Continental Shelf (Tunisia/Libyan Arab Jamahiriya)*. Both Judges considered that the Court's decision had been subjective and had blurred the distinction between a decision grounded on the principles and rules of law and one decided *ex aequo et bono*. The dissenting opinions of Judges Schwebel and Gros offers similar criticisms of the 1984 *Gulf of Maine* Judgment; *See also* Prosper Weil's "Towards Relative Normativity in International Law?" 77 *AJIL* 413 (1983).

[70] Oppenheim, *supra* note 34, at p. 724 and pp. 813–16.

as subject to their national jurisdiction and the recognition by developing countries that developed countries had greater technological and economic resources to exploit this new opportunity and benefit from it.

The legal regime established for the deep seabed in Part XI of UNCLOS aims at distributing the benefits of exploitation as widely as possible. It incorporates a notion of equity that includes a substantial element of distributive justice to refashion geography and compensate States for their unequal natural endowment—aims that were deliberately excluded as outside the ambit of equitable consideration in the rules concerning the continental shelf.[71]

(a) Relevant Equitable Principles

The principal that inspires this regime is that the Area (the deep seabed) and its resources are the "common heritage of mankind".[72] This principle embodies a broad notion of distributive justice and in that sense, it can be seen as an equitable principle. The concomitant of this principle are that "no State may claim or exercise sovereignty or sovereign rights over any part of the Area or it resources" or appropriate parts of it.[73] All rights in the resources are vested in mankind as a whole on whose behalf the Authority shall act.[74] Resources in the Area can only be exploited in accordance with UNCLOS provisions which set out the principles, procedures and managerial responsibility of the Authority and potential developers.[75] The common heritage of mankind principle embodies a number of elements relevant to the equitable sharing of costs and benefits of deep seabed exploitation which contrasts sharply with the equitable principles used in delimiting areas of the continental shelf.

(b) Relevant Factors in Equitable Apportionment

Article 140 provides that activities in the Area "shall be carried out for the benefit of mankind as a whole, irrespective of the geographical location of States, whether coastal or land-locked, and taking into particular consideration the interests and needs of developing States and of people who have not attained full independence..."[76] The Authority is mandated to provide for "the equitable sharing of financial and other economic benefits derived from activities in the Area" through any appropriate mechanism, on a non-discriminatory basis in accordance with Article 160(2)(f)(i).[77] This reiterates the need to take into particular consideration the interests and needs of developing States, particularly the least developed and land-locked among them and peoples who have not attained full independence in the development of payments and contribution to the Authority under Article 82.[78]

Unlike the law on continental shelf delimitation, these provisions expressly call for the consideration of socio-economic factors and economic needs, particularly of developing countries or other States disadvantaged by geography, to be taken into account in apportioning benefits. No definition of equity was included in UNCLOS. When the Convention enters into force, the Authority will have to determine how to give effect to the provisions concerning the common heritage of mankind. This may involve the elaboration of equitable sharing criteria to distribute any financial and other benefits to developing country Parties and other States who are not Parties to the Convention.

3. International Rivers

International rivers are examples of transboundary natural resources. These resources has been defined to mean a natural resource:

> "which physically crosses the boundary between an area under the national jurisdiction of a State and an area under the national jurisdiction of another State or an area beyond the limits of national jurisdiction to the extent that its use in an area under the national jurisdiction of one State may affect its use in an area under the national jurisdiction of another State or in an area beyond the limits of national jurisdiction or visa versa".[79]

As one State's use of a resource affects the use of the same resource by another, international law has developed principles to regulate the use of such resources in an equitable manner.

[71]For a discussion of the role of broadly conceived distributive notion of equity in the UNCLOS context, see *Franck and Sughrue, supra* note 9.

[72]UNCLOS, *supra* note 52, at art. 135. By virtue of Articles 7 and 11 of the 1979 Moon Treaty, the common heritage principle also applies to the exploitation of the non-living resources of the moon. Due to objections from a number of States, the legal status and universal applicability of the common heritage principles remains unclear. See Patricia Birnie & Alan Boyle, *International Law and The Environment*, Clarendon Press, Oxford (1992) pp. 120–22.

[73]*Id.* at art. 136.

[74]*Id.*

[75]*Id.* at arts. 138–55.

[76]*Id.*

[77]*Id.* at art. 160(2).

[78]Supra note 53.

[79]*Final Report of the Experts Group on Environmental Law on Legal Principles for Environmental Protection and Sustainable Development*, Munroe and Lammers, p. 37.

(a) Relevant Equitable Principles

In the case of international rivers (or watercourses) the relevant principle stipulates that States are entitled to a reasonable and equitable share in the beneficial uses of a transboundary resource.[80] This principle, regarded as a well established principle of international law, provides that no use or category of uses is inherently superior to any other use or category of uses.[81] Whether a use is reasonable, and a States' share of it equitable, has to be determined in light of all relevant factors in a particular case.[82]

The essence of this principle of equitable utilisation is that it prescribes a procedural technique aimed at reaching an equitable result in each concrete case rather than laying down a substantive norm with more or less specific content. The implementation of the principle thus requires negotiations between the States concerned in determining the equitable delimitation of the rights and obligations of each State. Many such negotiations subsequently result in the formulation of treaties to express the agreement.[83]

(b) Relevant Equitable Factors

No closed list of relevant factors in equitable apportionment has emerged during the course of the development of this area of law. A useful, non-exhaustive checklist of factors is provided in the Helsinki Rules, adopted by the International Law Association (ILA) in 1966. Although the Rules are non-legally binding, they have provided useful guidance as to what factors States should consider. These include:

(a) geography, hydrology of the river basin;
(b) climate of the basin;
(c) past utilisation of waters plus existing utilisation;
(d) economic and social needs of each basin State;
(e) population dependent on the waters of the basin in each State;
(f) availability of other resources;
(g) avoidance of unnecessary waste in the utilisation of waters of the basin;
(h) practicability of compensation to one or more of the basin States as a means of adjusting conflicts among uses; and
(i) the degree to which the needs of a basin State may be satisfied, without causing a substantial injury to a co-basin State.[84]

As a result of confusion about the applicability of the concept of an "international drainage basin", the International Law Commission (ILC) introduced the alternative concept of "international watercourse systems".[85] It also produced non-legally binding Draft Articles on the "Non-Navigational Uses of International Watercourses".[86] The principles and factors set forth are similar to the Helsinki Rules but are regarded as more authoritative. Accordingly the relevant parts of the ILC's Articles are produced in full in the Annex to this Paper.[87]

Neither the Helsinki Rules or the ILC Draft Articles, however, offer guidance as to the weight of the various factors they put forward as relevant to equitable utilisation. They stress, instead, that all the factors must be balanced with other factors and a decision made on the basis of the whole.[88] Unlike continental shelf delimitation, States have not used third-party settlement in disputes about international watercourses.[89] The lack of guidance in this regard from a body such as the ICJ has tended to limit the development and wider application of this body of law.

Whilst the procedural approach to resolving disputes about equitable utilisation has merits, it tends, for this reason, to give little normative guidance as to what should happen in a particular situation. This makes it difficult to draw general conclusions about what is and is not equitable. This, in turn, means that the usefulness and practical applicability of the procedural approach to other fields are limited. Moreover, a procedural approach works most effectively where there are only a few States involved as it becomes increasingly difficult to balance the interests and needs of a larger number of States.[90] Thus, it is difficult to rely on this approach alone in resolving disputes about global issues, such as climate change, that require the universal participation of States and a balancing of all their interests and needs.

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[80] Convention on the Protection and Use of Transboundary Watercourses and International Lakes, 17 March 1992, *UN Doc.E/ECE/1268; See also*, 1991 *ILC Draft Articles*; Munroe and Lammers, supra note 79, at p. 72; Schachter, *supra* note 9, at pp. 65–83.

[81] *Id.; See also* Oppenheim, *supra* note 34, at p. 586.

[82] *Id.*

[83] *Id.* at p. 73 which provides some examples of such treaties. *See also* Birnie and Boyle, *supra* note 72.

[84] Article V(2), *Helsinki Rules*.

[85] Oppenheim, *supra* note 34, at p. 588.

[86] Report of the ILC to the General Assembly, UN Doc. A/46/10/161 (1991).

[87] See e.g. text of Articles 6 and 7.

[88] Helsinki Rules Article V(3); ILC Draft Rules Article 7.

[89] *Birnie and Boyle, supra* note 72 at p. 222.

[90] *Id.* at p. 127.

4. Ozone Depletion

The 1985 Vienna Convention for the Protection of the Ozone Layer and its 1987 Montreal Protocol on Substances that Deplete the Ozone Layer address a global problem caused predominantly by developed countries' use of ozone depleting substances as part and parcel of their economic development.[91] Any long term solution requires not only that developed countries cooperate to ban their own ozone depleting activities, but also that developing countries follow suit thereby restraining their economic development options.[92]

Questions concerning the fairness of a universal ban were raised because developing countries neither significantly benefitted from developed countries' past emissions nor contributed significantly to the extent of the current problem through their own current emissions.[93] These questions posed significant obstacles to getting the cooperation and participation of developing States in a legal regime that required their participation for its future success.[94] The participation in the Montreal Protocol of a large number of developing country Parties is widely viewed as a measure of its success in addressing the fairness or equity concerns of developing countries.[95] As a result, its approach was extensively discussed as a "model" by negotiators of the Climate Change Convention.[96]

(a) Vienna Convention: Relevant Equitable Principles and Factors

It may be surprising to note, therefore, that the word "equity" is not mentioned in the Vienna Convention and that the term "equitable" is found only once in Annex II concerning the collection and sharing of information which states:

> "The Parties to the Convention recognize that the collection and sharing of information is an important means of implementing the objectives of this Convention and of assuring that any actions that may be taken are appropriate and **equitable**. Therefore, Parties shall exchange scientific, technical, socio-economic, business, commercial and legal information".(emphasis added)[97]

This list of information in the second sentence, elaborated in the main body of Annex II, is significant in that it suggests the kinds of considerations Parties might consider relevant for reaching appropriate and equitable decisions about future "actions". In this regard it may be worth noting that "technical" information includes the availability and costs of substitutes for substances that deplete the ozone layer as well any limitation and risks these pose.[98] Socio-economic and commercial information includes production and production capacity, use and use patterns, imports and exports and their costs, risks and benefits of human activities which may indirectly modify the ozone layer and impacts of regulatory action to control these activities.[99]

It is also worth noting that although the Vienna Convention does not explicitly contain an article called "equitable principles", its Preamble does provide an indication of some of the equitable principles and considerations that the Parties considered relevant to allocating future rights and responsibilities between States. For example, the third Preambular paragraph states that Parties

> "Tak[e] into account the circumstances and particular requirements of developing countries".[100]

The substantive provisions of the Convention reflect this provision. For example, the general obligations in Article 2 provide that the measures Parties shall take should be "in accordance with the means at their disposal and their capabilities".[101] Article 4 also requires the needs of developing countries to be taken into account in the development and transfer of technology and knowledge. Whilst the Vienna Convention is criticised for being "largely an empty framework", it incorporates important reference points for the development of an equitable legal regime to combat ozone depletion.[102]

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91 For a detailed background to the negotiation of these instruments see Richard Benedick, *Ozone Diplomacy: New Directions in Safeguarding the Planet*, Harvard University Press (1991).

92 *Id.*

93 *See* Armin Rosencranz and Antony Scott, "Montreal Protocol:Bringing the Developed World on Board", 20 *Envtl. Pol'y & L.* 201 (1990).

94 *Id.*

95 For a discussion of the international equity issues involved and their relevance to climate change see e.g., Gunther Handl, "International Efforts to Protect the Global Atmosphere: A Case of Too Little, Too Late?" 1 *EJIL* 250 (1990).

96 Daniel Bodansky "The United Nations Framework Convention on Climate Change" 18 *Yale J. Int'l L.* 451 (1993), at pp. 493–96.

97 *Vienna Convention for the Protection of the Ozone Layer* (hereinafter Vienna Convention), 22 March 1985, Annex II para. 1. The Vienna Convention is reprinted in 26 *ILM* 1529.

98 *Id.* at Annex II, para. 4.

99 *Id.* at Annex II, para. 5.

100 *Id.* at Preamble para. 3.

101 *Id.* at art. 2(2).

102 See, e.g., *Birnie and Boyle, supra* note 72 at p. 406.

(b) Montreal Protocol: Relevant Equitable Principles and Factors

This regime is further developed in the provisions of the 1987 Montreal Protocol and its subsequent amendments.[103] Like the Vienna Convention, the amended Protocol refers to the concept of equity only once.[104] The sixth Preambular paragraph states that Parties to the Protocol are:

> "Determined to protect the ozone layer by taking precautionary measures to control **equitably** total global emissions of substances that deplete it, with the ultimate objective of their elimination on the basis of developments in scientific knowledge, taking into account technical and economic considerations and bearing in mind the development needs of developing countries".(emphasis added)[105]

Although not legally binding as a substantive obligation, this principle is a significant reference point in the overall context of the Protocol as it explains the considerations Parties consider relevant to the determination of substantive rights and responsibilities to protect the ozone layer. These considerations are elaborated in the seventh and ninth Preambular paragraphs which explain that the special needs of developing countries include the provision of additional, predictable flows of funds and transfers of alternative technologies from developed countries.[106]

The following list provides a brief outline of the way in which the Protocol's substantive provisions give practical expression to different elements of the above paragraphs. It is the use of legal techniques to implement the various equitable principles and considerations that distinguishes the Montreal Protocol from other conventions and has led to the Protocol being regarded as a "model" for other global agreements, including the Climate Change Convention.[107] The techniques used in the Montreal Protocol include:

- differentiated standards for developed and developing country Parties including: the provision of grace periods for compliance for the latter; allowing increased developed country Party production to enable developing country Parties to meet their "basic domestic needs"; and allowing developing countries to base their emission entitlements on a per capita basis;[108]
- financial assistance to developing countries, over and above overseas development assistance (ODA), to cover "all agreed incremental costs" and enable compliance;[109]
- transfer of technology, especially of best available, environmentally safer substitutes under fair and most favourable conditions, facilitated by the Protocol's financial resources if necessary;[110]
- limited operation of a tradeable permit or joint implementation scheme to achieve "industrial rationalisation";[111]
- an acknowledgment that developing countries' abilities to comply is conditional upon the "effective implementation" of developed countries' financial cooperation and technology transfer obligations;[112]
- an innovative, "non-compliance procedure" to assist resolution of disputes, including those concerning the implementation of the above between developed and developing countries, including those involving financial transfers, to avoid confrontational enforcement and dispute settlement machinery ;[113] and finally,
- procedural techniques such as non-unanimous but binding decision-making procedures requiring a majority from both developed and developing country Parties, to facilitate continual assessment, review and adoption of further "equitable" control measures in a flexible manner.[114]

It is important to note that the differentiated standards applicable to developing country

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[103] The following discussion refers to the text of the 1987 *Montreal Protocol on Substances that Deplete the Ozone Layer* as Adjusted by the Second Meeting of the Parties, London, 27–29 June 1990, Further Amended by the Third Meeting of the Parties, Nairobi, 19–21 June 1991 and the Fourth Meeting of the Parties, Copenhagen, 23–25 November 1992.

[104] *Adjustments and Amendments to the Montreal Protocol on Substances that Deplete the Ozone Layer*, 29 June 1990, *reprinted in* 30 *ILM* 537 (hereinafter London Amendments).

[105] *Id.* at art. 1.

[106] Full text of this paragraph is reproduced in the Annex to this paper. The Preambular paragraphs: "...special provision is required to meet the needs of developing countries, including the provision of additional funding resources and access to relevant technologies, bearing in mind that the magnitude of funds necessary is predictable...and can...make a substantial difference in the world's ability to address the...problem of ozone depletion".

[107] *See generally*, Benedick, *supra* note 91; Handl, *supra* note 95.

[108] London Amendments, *supra* note 104, at art. 2(C) and art. 5.

[109] *Id.* at art. 10(1).

[110] *Id.*

[111] *Id.* at arts. 2(5) and 2(8)(a) of the 1987 Montreal Protocol.

[112] *Id.* at arts. 5(5), (6) and (7). This could amount to a possible variation of traditional international rules on responsibility and liability for breach of treaty obligations and environmental damage resulting from such a breach.

[113] Montreal Protocol on Substances that Deplete the Ozone Layer, 16 September 1987, *reprinted in* 26 *ILM* 1550 (hereinafter Montreal Protocol), Article 8 and London Amendments, *supra* note 104, at Annex III; *see also*, Jake Werksman, "Designing a Compliance System for the United Nations Framework Convention on Climate Change", Chapter 2, FIELD Report on Improving Compliance with International Agreements (forthcoming).

[114] *See e.g.* Article 2(9) and Articles 6 and 7 Montreal Protocol as amended by London Amendments, *supra* note 104.

Parties are intended to allow each of these Parties "to meet its basic domestic needs". The Protocol does not define this term but it could imply a value judgment about non-essential needs that another Party could use to challenge a developing country Party's use of its favourable standards to pursue non-basic needs. It is also important to note that the differentiated standards do not give developing country Parties an unquantifiable, indefinite right to increase emissions whatever their future socio-economic needs or population.

Many of the techniques used in the Montreal Protocol also feature in the Convention on Biological Diversity and the Climate Change Convention. Their inclusion in these major global treaties might prompt the conclusion that they are "equitable techniques" the use of which is implicit in international environmental treaties where equity issues between developed and developing States are concerned. It is important to recognise however, that the use of these techniques is *one* way of implementing the equitable principles and considerations that Parties considered relevant to the Montreal Protocol context.

Other techniques were possible—and remain so. These could include for example, the development of rules on "liability" for environmental damage. At the international level, the traditional concept of liability, a classic way of implementing the polluter pays principle, has been modified by developing countries to argue that developed countries (rather than polluting companies) should be held responsible for their historic contributions to global degradation, caused in large part by their indulgent, consumerist lifestyles, and developing countries compensated for foregoing their development options to take a similar path to economic development.[115]

The fact that Parties to the Montreal Protocol chose to establish a financial mechanism based on the concept of "incremental costs", rather than adopt the main responsibility/compensation approach, to give effect to equitable considerations, is in itself a significant fact that should not be overlooked.

5. Biological Diversity

UNEP's 1992 Convention on Biological Diversity, signed by 153 States and the EC at UNCED, entered into force on 21 December 1993.[116] The Convention aims to conserve the world's rapidly dwindling genetic, species and ecosystem biological diversity ("biodiversity") by promoting conservation measures but at the same time allowing States to benefit from its sustainable use.[117] Article 1 of the Convention states that:

> "The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the **fair and equitable sharing** of the benefits arising out of the utilizations of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and technologies, and by appropriate funding".(emphasis added).

As much of the world's biodiversity is found, and is being lost, in developing countries, policies to address biodiversity loss impose a larger and more direct burden on these countries' economic and developmental policies than a global problem such as ozone depletion.[118] This is because most biodiversity conservation measures have an adverse short term impact on key industries, such as forestry and agriculture, which developing countries are compelled to expand to meet the immediate needs of their growing populations, and to service their international debt obligations.[119]

The conservation/development and developed/developing country conflicts are further exasperated because while developed countries bear much of the cost of biodiversity conservation, they are rarely able to realise biodiversity's full economic value.[120] Developed country industries such as the biotechnology, pharmaceutical, chemical, agricultural and cosmetics industries, all of which depend on open access to developing countries' genetic diversity, can appropriate the full economic value of this resource, and often the knowledge of local communities, without making any payment to these communities and the States in which the resources are found.[121]

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[115] For example, in the context of ozone depletion, India submitted that it would have to be paid $2 billion to be compensated for opportunity costs incurred as a result of their participation in the Protocol, *see* in Handl, *supra* note 95. Similar arguments were made in the climate change context by developing countries such as India and China who characterised them as the "main responsibility" principle. See, Paper No. 17, submitted by the Chinese Government to the second session of the INC; *See also* Anil Agarwal and Sunita Narain, *Global Warming in an Equal World: A Case of Environmental Colonialism* (1991) and Bodansky, *supra* note 96, at p. 498.

[116] *Convention on Biological Diversity* (hereinafter the Biodiversity Convention), 5 June 1992, 31 *ILM* 822.

[117] For a background to the Biodiversity Convention negotiations and an explanation of its key provisions see Clare Shine and Palitha Kohona, "The Convention on Biological Diversity: Bridging the Gap Between Conservation and Development", Vol. 1.3, p. 278, *RECIEL* (1992).

[118] *Id.* at p. 280.

[119] *Id.* p. 280.

[120] See Pat Mooney, "Genetic Resources in the International Commons", Vol. 2.2, *RECIEL* (1993).

[121] *Id.*

Developing countries are particularly aggrieved when the monopoly profits, products, technologies and knowledge of such industries are protected through intellectual property rights.[122]

Against this background, the principles and provisions of the Biodiversity Convention aim to bridge the gap between conservation and development and the divergent short term interests of developed and developing countries.

(a) Relevant Equitable Principles

In addition to the objectives stated in Article 1, the need for "equitable sharing" or "fair and equitable" sharing of benefits is mentioned in the Biodiversity Convention at least four times. These references, found in the Preamble and the substantive provisions of the Convention, concern the desirability of sharing the benefits of utilisation of the knowledge, innovations and practices of indigenous and local communities with the communities concerned,[123] sharing the benefits of the results of research and development arising from the commercial or other utilisation of genetic resources with Parties providing access to such genetic resources,[124] and finally, sharing the results and benefits arising from biotechnologies based on genetic resources with Parties providing those resources.[125]

The provisions on "equitable" benefit sharing are closely related to the Convention's other principles and provisions and the reference to "equitable" must be interpreted in that context. It should be noted however, that one of the most important provisions is Article 3 which states only one "Principle"—Principle 21 of the UN Stockholm Conference on the Human Environment which provides that States have the sovereign right to exploit their resources subject to not causing harm beyond the limits of their national jurisdiction.[126] This principle of sovereignty over natural resources forms an essential bedrock of the Convention and is invoked to justify States having "the authority to determine access to genetic resources" which must be on mutually agreed terms, subject to the principle of prior informed consent and in accordance with national legislation.[127]

Other important principles include the Convention's designation of biological diversity as a "common concern of mankind",[128] and its acceptance that States are responsible for the conservation and sustainable use of biodiversity for the benefits of present and future generations. For the first time in international law, sustainable use is defined in Article 2 to mean

> "use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations".[129]

This reference to future generations introduces the notion of balancing the needs of the present generation with the needs of future ones ("intergenerational equity").[130] These provisions, which might be referred to as the "common responsibilities" provisions, are balanced by other principles that point to "burden-sharing" or the need for differentiating the implementation of these responsibilities. For example, language reminiscent of that of the Montreal Protocol provides that receipt of additional funds and technology can "make a substantial difference in the world's ability" to address biodiversity loss and thus assist compliance.[131] Likewise, "special provision is required to meet the needs of developing countries, including the provision of new and additional financial resources and appropriate access to relevant technologies".[132] Together these various principles can be referred to as the principle of "common but differentiated responsibilities".[133] This principle, encapsulating broader notions of equity and the need to take developing country needs into special consideration, has developed in international law in recent years and appears to be an emerging principle of international law of general application.[134]

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[122] *See* Farhana Yamin and Darrell Posey, "Indigenous Peoples, Biodiversity and Intellectual Property Rights", Vol. 2.2, *RECIEL* (1993).

[123] Biodiversity Convention, *supra* note 116, at art. 8; *See also* Preambular paragraph 12 on indigenous and local communities. The text of these, and the following articles are reproduced in the Annex to this paper.

[124] *Id.* at art. 15.

[125] *Id.* at art. 19.

[126] The full text of Principle 21 is reproduced in the Annex to this Paper.

[127] Biodiversity Convention, *supra* note 116, at art. 15(1), (4) and (5).

[128] *Id.* at Preambular para. 3.

[129] *Id.* at art. 2; *See also* Preambular paras 5 and 23.

[130] *See* Edith Brown-Weiss, *In Fairness to Future Generations: International Law, Common Patrimony and International Equity* (1989); *See also*, Gundling, "Our Responsibility to Future Generations", 84 *AJIL* 190 (1990) which also contains a number of other useful articles on intergenerational equity.

[131] Biodiversity Convention, *supra* note 116, at Preambular para. 15.

[132] *Id.* at Preambular para. 16.

[133] Sands, *supra* note 9, at chapter 6.

[134] *Id.*; *See also*, Trindade and Attard reporting the discussions of UNEP's Group of Legal Experts to Examine the Implications of The "Common Concern of Mankind" Concept on Global Issues at p. 10.

It is important to note however, that the "burden-sharing" provisions of the common but differentiated responsibilities principle tend to focus attention on finding techniques or mechanisms to balance the unequal needs of the present day generation (intragenerational equity) rather than focusing on intergenerational inequities. This focus leads to finding ways to address the imbalance of economic resources between North and South rather than the ecological balance between present/future generations.[135] This fact highlights the problem that whilst the international community acknowledges its *moral* obligation to consider the needs of future generations, it remains undecided about whether, and how, to give this moral concern a legal form.[136]

(b) Relevant Equitable Factors

Like the Montreal Protocol, the Biodiversity Convention contains a number of substantive provisions that give practical effect to equity concerns, including the need to take developing countries' needs into special account. These include the following techniques:

- new and additional financial assistance to developing countries, over and above ODA, to cover "agreed full incremental costs" and enable compliance;[137]
- transfer of environmentally safe technology, including biotechnology and technologies covered by intellectual property rights on "fair and most favourable" terms, facilitated by the financial mechanism if necessary;[138]
- obligations for developed and developing countries to equitably share benefits arising from utilisation of the knowledge, innovations and practices of indigenous and local communities with the communities concerned;[139]
- obligations to advance priority access to developing country Parties and to equitably share the benefits and the results of research and development arising from the commercial or other utilisation of genetic resources, particularly with developing country Parties providing access to such genetic resources;[140]
- obligations to advance priority access to developing countries and to equitably share the results and benefits arising from biotechnologies, based on genetic resources, particularly with developing country Parties providing such genetic resources;[141]
- acknowledgement that developing country Parties' abilities to comply are conditional upon the "effective implementation" of developed country Parties' financial cooperation and technology transfer and that "economic and social development and the eradication of poverty" are the first and overriding priorities of the developing countries;[142]
- in funding and technology transfer, special consideration to be given to least developed countries,[143] and consideration to be given to special conditions resulting from the dependence on distribution and location of biodiversity within developing country Parties, especially small island states and those that are environmentally vulnerable.[144]

The Convention does not define the various terms relating to "equitable" benefit sharing. If the implementation of these provisions became subject to the third-party dispute settlement procedures in Article 27, it is clear that an extensive range of principles and factors would have to be considered as relevant in determining the interpretation of Convention. Many of these have been outlined above but it should be borne in mind that other principles and factors, such as the principle of sustainable use, which covers inter and intra-generational issues, might also be considered relevant.

C. Equity in the Climate Change Convention

What is the role of equity in the Climate Change Convention so far as rights and responsibilities to protect the climate system are concerned? The Convention specifically mentions "equity" in Article 3.1 concerning principles, and uses the term "equitable" in Article 4.2(a) concerning the specific Commitments of Annex I (developed country) Parties.[145] Like the Biodiversity Convention, the terms "equity" and

[135] See for example, the mechanisms created by the Montreal Protocol as well as those created by the Biodiversity and Climate Change Conventions discussed below.

[136] *Birnie and Boyle, supra* note 72 at p. 212 provide a limited number of examples in which the intergenerational concept has been implemented in international law.

[137] Biodiversity Convention, *supra* note 116, at art. 20(2).

[138] *Id.* at art. 20.

[139] *Id.* at art. 8; *See also*, the twelfth preambular paragraph on indigenous and local communities. The text of these, and the following articles are reproduced in the Annex to this paper.

[140] *Id.* at art. 15, reproduced in the Annex to this paper.

[141] *Id.* at art. 19, reproduced in the Annex to this paper.

[142] *Id.* at art. 20(4).

[143] *Id.* at art. 20(5).

[144] *Id.* at art. 20(6) and (7).

[145] As stated previously, the reference to "equitable" in Article 11.2 concerning the financial mechanism relates to concerns about participation and universal representation, rather than burden-sharing and it will not be examined in this Paper.

"equitable" in the Climate Change Convention in relation to climate change protection are closely related to other principles and provisions and must be interpreted in the light of the Convention's overall approach and context. This is particularly important in the Climate Change Convention because equity is mentioned in the context of Article 3.1, often referred to the principle of common but differentiated responsibility which is one of the five principles found in Article 3.

This section considers what legal consequences flow from the mention of "equity" and "equitable" in the Climate Change Convention in Articles 3.1 and 4.2(a) by addressing the following legal issues or questions:

- What is the nature and legal status of the principles in Article 3. In particular, what is the relationship of the principle contained in 3.1 to other principles (in Article 3, the Preamble or otherwise) and how are these principles intended to "guide" Parties' to achieve the objectives of the Convention or implement its provisions;
- What is the meaning or legal significance of Article 3.1 in the event of a dispute between Parties concerning the interpretation or implementation of a substantive provision such as Article 4.2(a). In particular, what kinds of factors or circumstances could Parties put forward as relevant to an equitable determination of their rights and obligations under the Convention.

Legal Status and Nature of the Convention's Principles

The Convention comprises several kinds of provisions of different legal status. The Preamble, which itself does not create substantive legal rights and obligations that would give rise to a cause of action, generally states the background, purposes and context of the agreement.[146] The remainder of the Convention creates binding legal rights and obligations for Parties. However, the normative consequences of various provisions dealing with the definitions,[147] objective,[148] principles,[149] and remaining substantive provisions,[150] differ because of the specificity of the legal rights and obligations created by them. Accordingly, their legal status as rules, which create mandatory standards of State behaviour, differs.[151] The definitions and substantive provisions certainly fall into the category of rules, although some are rather ambiguous in parts.

The legal status of the principles and the objective is complicated because during negotiations, delegations differed in their views as to the purpose of including these provisions in the substantive part of the Convention.[152] The inclusion of such matters in the main body of the Convention, rather than in the Preamble where they are more traditionally found, was intended to ensure that they carried greater political and legal significance than matters mentioned in the 23 paragraphs of the Preamble.[153] Disagreements about the legal significance of placing the principles in the main body of the Convention explain, for example, the appearance of the unusual footnote to the title of Article 1.[154] The disagreements also explain why some commonly accepted principles, such as the principle of sovereignty, were relegated to the Preamble.[155]

The inclusion of principles in the main body of the text reflects negotiators' anxiety about a critical legal issue that has significant bearing on future dispute settlement between Parties which is:

- can the principles in Article 3 provide an independent source of law to determine Parties' legal rights and obligations (independent, that is, of the substantive provisions of the Convention).

This question is important as one effect of an affirmative answer would be to "open" up the interpretation of Convention's text such that principles and factors currently perceived to have been permanently jettisoned or resolved during the course of negotiations could then be re-considered in the course of a dispute or in the development of Convention's provisions. Accordingly, it is important to understand if the Convention can be interpreted to allow Article 3 to play this broader, "opening" up role.

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[146] The Preamble can therefore have significant legal implications. See Article 31, 1969 Vienna Convention on the Law of Treaties (1969 Vienna Convention).

[147] Climate Change Convention, *supra* note 2, at art. 1.

[148] *Id.* at art. 2.

[149] Id. at art. 3.

[150] *Id.* at arts. 4–26 and annexes.

[151] On the distinction between principles and rules, *see* Dworkin, *supra* note 12.

[152] See Bodansky, *supra* 96, at pp. 497–98.

[153] *Id.* at pp. 497–505.

[154] The footnote states the "[T]itles of articles are included solely to assist the reader". After their failure to have all the principles relegated to the Preamble, the USA delegation insisted on the insertion of this footnote in the hope that this would weaken the legal effect of the principles. In view of the wording of the footnote, it is doubtful however, whether this strategy is actually effective. See Philippe Sands, "The UN Framework Convention on Climate Change", *RECIEL*, Vol. 1.3 (1992).

[155] *Id.* at p. 272.

International legal rules on interpretation provide that "[a] treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose".[156] For the purposes of interpretation, the context includes the preamble and any annexes.[157] Where the meaning is ambiguous or leads to a manifestly absurd or unreasonable result, "[r]ecourse may be had to supplementary means of interpretation, including the preparatory work of the treaty and the circumstances of its conclusion..."[158]

It is worth recalling the chapeau of Article 3 in full which states:

> "In their actions to achieve the objectives of the Convention and to implement its provisions, the Parties **shall be guided,** *inter alia,* by the following..."(emphasis in original).

To be guided means "to lead or direct in the course of action" or "to determine the course of (events, etc.)..."[159] The reference to "shall" and "the following" indicates that Parties must consider the relevance of *all* the principles stated in the remainder of Article 3. The Convention does not provide an indication of the weight to be given to each principle. The continental shelf case law of the ICJ, and the other international legal agreements examined in Part B, suggest that the weight to be given to each principle would have to be looked at in the context of a particular case and cannot be generalised.[160]

How do the principles in Article 3 "guide" the Parties in the achievement of the Convention's objectives and the implementation of its provisions? This question is extremely difficult to answer for at least three reasons. First, it is difficult to apply principles in the absence of a particular dispute. This was acknowledged by the ICJ in the 1969 North Sea Continental Shelf Judgment where the Court stated that it was difficult to apply equity in the abstract which had in any case, to be applied in accordance with well established principles of law.[161]

This points to the second reason which is particularly relevant to the Climate Change Convention. The Convention establishes a **new** legal regime to protect the climate system. The principles of this regime, including those found in Article 3, have some basis in the history of international law but undoubtedly represent new or emerging principles of the international legal order. The meaning of the five principles contained in Article 3 is by no means settled and the fact that they are inextricably linked only complicates the task of clarifying the meaning and import to be given to any one of them.

A third reason arises from the reference to "inter alia" in the chapeau. This indicates that the list of principles in Article 3 is not closed. On the contrary, where relevant, principles not mentioned in the Convention could also be considered. It would appear that a court or tribunal called upon to apply Article 3 would, in every situation, have to address whether any principles not included in the Convention would be relevant to a particular situation and then consider their relative weight.[162] For these reasons at this early stage of the Convention's evolution, it is difficult to state how its Parties will use the provisions of Article 3 as guidance.

It is important to note however, that the wording of the chapeau does not appear to limit the Parties to using the principles for this "guiding function" alone. Article 3 can be used to guide Parties consideration of questions concerning implementation of the Convention's substantive provisions. But it can also be used to consider questions relating to the overall achievement of the objectives of the Convention. The wording of Article 3 does not appear therefore, to limit the role of the principles such as to exclude the possibility that they could provide an independent source of legal rights and obligations.[163]

In this context, it is relevant to note that the USA had proposed additional changes to Article 3 to make clear that a Party could not be found in violation of this Article in dispute settlement proceedings under Article 14.[164] As neither the text of Article 3 or Article 14 incorporate this concern, it is clear that the Convention certainly does not exclude the possibility that Article 3 can be a source of legal rights and obligations for the Parties of the Convention, and not just be limited to playing a restrictive function in interpreting the rights and obligations already spelt out in the substantive provisions of the Convention.

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[156] Article 31, 1969 Vienna Convention on the Law of Treaties (Vienna Convention).

[157] *Id.* at art. 31(2).

[158] *Id.* at art. 32.

[159] *The Shorter Oxford English Dictionary*, third edition, Clarendon Press (1972).

[160] See text accompanying *supra* note 51.

[161] The ICJ stated "(i)t is not a question of applying equity simply as a matter of abstract justice, but of applying a rule of law which itself requires the application of equitable principles, in accordance with the ideas that have always underlain the development of the legal regime...".

[162] The insertion of the "*inter alia*" was suggested by the USA, purportedly to limit the potential legal implications of Article 3. See Bodansky, *supra* note 96, at p. 502. As the inclusion of "*inter alia*" widens the scope of available principles, it is questionable whether this strategy will prove effective.

[163] It is possible to argue that if the "and" between "the Convention" and "to implement" is read as a conjunctive (rather than disjunctive) "and" that this possibility is excluded. There does not appear to be any strong reasons to prefer the former.

[164] See Bodansky, *supra* note 96, at p. 502.

As stated previously, this broader "opening up" function is potentially significant as it could provide a basis for reconsidering Parties' existing rights and responsibilities under the Convention as well as the development of new ones in a way not currently envisaged by its other substantive provisions. This is an important point to note for both developed and developing country Parties as many parts of the Convention including, Article 4.2(a) and (b) relating to developed country Party commitments which mentions the term "equitable", are widely recognised to be ambiguous, proving that the legal status and nature of Article 3 may be of critical importance in the interpretation and development of this and other provisions in the Convention.

One example of this important, broader role Article 3 might play concerns the recent INC debates on joint implementation in which a number of countries, including the USA and Norway, argued during the sessions that the Convention allows both developing and developing country Parties to participate in joint implementation.[165] The Convention's substantive provisions in Article 4.2(a) appear to limit joint implementation to developed country Parties.[166] The reference to Article 3 by the USA and others, to provide or support a legal basis to allow developing country Parties to participate in joint implementation may therefore be a significant, early indication that at least some of the Convention's Parties may wish to use Article 3 not only in its restrictive "guiding" function but also in its broader function to determine rights and obligations in a way not currently envisaged by its other substantive provisions and which would fundamentally alter the existing balance of rights and obligations in the Convention between developing and developing country Parties.[167]

Meaning of Equity in Articles 3.1 and 4.2 (a)

The above discussion has focused on the nature and legal status of Article 3 as a whole. The following section addresses the meaning or significance of Articles 3.1 and 4.2(a). For the reasons set out in the foregoing discussion, it is difficult to be categoric about the meaning of each of these references. By highlighting some salient points, it is hoped that the following discussion will contribute to a better understanding of the significant role that equity might play in the implementation and future development of these provisions.

(i) Common Responsibilities

The first part of Article 3.1 restates Preambular paragraph 23 providing that Parties should protect the climate for the benefit of present and future generations. The reference to "protect" focuses attention on the essentially preventative aspects of this common endeavour.[168] These preventative and common aspects create a basis to argue that protection of the climate might, in due course, crystallise into an "obligation egra omnes" or become part of "jus cogens".[169]

Egra omnes obligations are certain, legal obligations of universal application which, because they are of interest to all States create rights and obligations for all, irrespective of whether all States were involved in their formulation.[170] If the obligation to protect the climate were to become recognised as an obligation egra omnes, it might allow a State to institute legal proceedings against another State in its capacity as a member of the international community.[171] It could therefore allow States who were not able to show harm to their own interests to take enforcement proceedings against another State or group of States to force compliance with the Climate Change Convention. Rules of jus cogens are rules binding on all States that are of such fundamental importance that, once created, do not permit derogation other than through the creation of another rule of the same fundamental character.[172] If protection of the climate were accepted as a rule of jus cogens, no State or group of States could unilaterally decide that it was no longer obliged to protect the climate.

An "equitable" implementation of the Climate Change Convention may necessitate developing both concepts further to avoid Parties to the Convention unfairly imposing all the burden of protecting the climate onto others by unilaterally "opting out" of their obligations. As the law presently stands, any Party to the Convention

[165]Remarks made by delegations during INC 8. See also Norway submissions at INC 8 and recent country submissions on joint implementation and the Secretariat's background papers for INC 9 and INC 10 on joint implementation.

[166]This point was made by a number of developing countries such as Argentina, Malaysia, Tunisia at the INC sessions. *See also*, Farhana Yamin, "The Climate Change Convention and Joint Implementation: Legal, Institutional and Procedural Issue", FIELD Working Paper, 15 August 1993.

[167]On this see, Farhana Yamin "The Climate Change Convention: Development of Criteria for Joint Implementation". FIELD Working Paper, February 1994.

[168]*Supra* note 134.

[169]*Id.*

[170]Oppenheim, *supra* note 34, at p. 5. There is no clear enumeration however, of what rights and obligations would be created.

[171]*Id.* The nature of egra omnes obligations obviates the need to prove a special legal interest before instituting a case. An initiating State may not need to be a Party to the Convention.

[172]*Id.* at p. 7. Again, there is no agreement as to which international rules actually have this character.

has the right to opt out or withdraw from the Convention three years from its entry into force for that Party.[173]

The second sentence of Article 3.1 focuses attention on the adaptive, rather than preventative, aspects of climate change. Although adaptation forms part of Parties' common responsibilities, Article 3.1 provides that developed country Parties "should take the lead in combating climate change and the adverse effects thereof". This reference to adaptation clearly indicates that the allocation of common responsibilities to prevent climate change must be considered in the light of the burdens and benefits caused by adapting to climate change. The development of further rights and responsibilities to prevent climate change, particularly for developing country Parties, must be considered in the light of the burden they might have to bear adapting to climate change and the assistance they receive from developed country Parties in this respect.

(ii) Differentiated Responsibilities—Intergenerational Equity Issues

Common responsibilities do not have to be shouldered equally by members of the international community but are differentiated according to responsibility (past contribution to the problems) as well as respective capabilities (present and future capacity, economic or otherwise, to deal with the problem). This reiterates one general principle of equity identified by the ICJ in the continental shelf litigation that "equity does not necessarily imply equality".[174]

Before discussing differentiated burden-sharing between countries, it is important to note that common responsibilities are exercised "for the benefit of present and future generations". The reference in Article 3.1 to present and future generations reiterates the references to intergenerational equity in UNGA Resolutions and the Preamble.[175] It also creates an immediate link between the concept of common but differentiated responsibilities with the concept of sustainable development which to the extent that it is commonly understood, denotes a requirement to examine the needs and interests of future generations to assess what limits these might impose on the use of resources by the present generation.[176]

Article 3.4 states that Parties "have a right to, and should, promote sustainable development" but that "economic development is essential for adapting measures to address climate change".[177] Arguably, the Convention does not oblige Parties to pursue sustainable development or impose a clear obligation to sustainable use in the way the Biodiversity Convention does.[178] In fact the substantive provisions of the Convention do not mention the term "sustainable development" as such.[179]

The somewhat ambiguous nature of obligations to sustainable development, and the lack of institutional or other mechanisms to safeguard the needs and interests of future generations in the Climate Change Convention, reflect, in part the general difficulty of putting intergenerational needs and interests into effect.[180] However, their absence from the main body of the Convention also indicates that, rightly or wrongly, the negotiators of the Convention were more concerned to address **intragenerational equity** issues than intergenerational ones. Accordingly they choose to deploy their efforts to creating institutional mechanisms and other techniques to address intragenerational imbalances in financial and resources terms, particularly between developed and developing country Parties rather than imbalances between present day and future generations.

(iii) Differentiated Responsibilities—Intragenerational Equity

By contrast with the provisions on intergenerational issues, the Convention's intragenerational provisions concerning differentiated responsibilities between Parties, are dealt with in a detailed and comprehensive fashion in the substantive body of the Convention. The Convention differentiates rights and responsibilities between three categories of Parties—developing, developed and those with economies in transition. Article 4.1 entitled "Commitments" creates obligations for all Parties. Article 4.2 creates additional substantive

[173] Climate Change Convention, *supra* note 2, at art. 25.

[174] *See* text accompanying *supra* note 51; see also text accompanying *supra* note 43.

[175] Climate Change Convention, *supra* note 2, at preambular paragraphs 11 and 23.

[176] See Sands, *supra* note 12.

[177] Climate Change Convention, *supra* note 2, at art. 3.4.

[178] *See generally supra* notes 116–44 and accompanying text.

[179] The Convention does however, require Parties to "promote sustainable management" of sinks and reservoirs taking into account their "specific national and regional development priorities". Climate Change Convention, *supra* note 2, at art. 4.1(a). It also refers to the need for Parties to ensure that "economic development...proceed(s) in a sustainable manner", (Article 1), and the need for an "international economic system that would lead to sustainable economic growth and development in all Parties" (Article 3.5).

[180] *Supra* note 178.

obligations for developed country Parties listed in Annex I which includes Parties with economies in transition. Article 4.3 and 4.4 create additional financial obligations for developed country Parties listed in Annex II which does not include Parties with economies in transition. The financial assistance is to be provided to developing country Parties. Article 4.5 concerning Annex II Parties' obligation to facilitate technology transfer to all Parties allows Parties in economies to be the "beneficiary" but stresses the particular importance of transfer of technology to developing country Parties.

As regards the implementation of the differentiated substantive commitments created by Articles 4.1–4.5, Articles 4.6–4.10 provide a range of factual or other circumstances that must be given consideration.[181] These Articles are therefore of particular relevance in considering what might or might not count as a relevant "equitable factors" in a particular case.

Article 4.6 provides that a certain amount of "flexibility" must be given to Parties with economies in transition in the implementation of their Article 4.2 (a) obligations. Article 4.7 makes the implementation of developing country Parties commitments conditional on the implementation by developed country Parties of their financial and technology transfer commitments and recognises that "economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties". Article 4.8 provides that Parties are required to give full consideration to the specific needs and concerns of the developing country Parties with the special features referred in (a)-(i) of this Article. These features include for example, geographical, biological and economic factors such as whether a country is small island, is prone to natural disasters or desertification, or highly dependent on income from fossil fuel consumption or production.[182] Article 4.9 provides that full account must be taken of least developed countries for funding and technology transfer. Finally, Article 4.10 is also relevant as it provides that so far as implementation is concerned, consideration should be given to all Parties whose economies are highly dependent on income generated from the production or consumption of fossil fuels or energy intensive products and for which Parties have serious difficulties in switching to alternatives.[183]

This brief outline of factors which the Convention prescribes as relevant is in marked contrast to the kinds of factors considered relevant by the ICJ in the continental shelf cases. The specific inclusion of socio-economic factors, as well as natural or geographic factors, means that factors which have a close bearing on distributive justice would have to be addressed. It is unclear how the Court would then apply the general equitable principle enunciated in those cases that the application of equity cannot concern distributive justice.[184] This underscores yet again the importance of the fact that the application of equity cannot be generalised but must depend on the context of each case and the legal regime applicable to it.

This is important in considering the interpretation and implementation of Article 4.2 (a) which requires developed country Parties to adopt national policies and measures to modify longer trends in greenhouse gas emissions (GHGs) by limiting their anthropogenic emissions of GHGs and enhancing and protecting their sinks and reservoirs. In deciding whether they are "taking the lead" in this regard, Article specifically provides that account must be taken of:

> "the differences in their starting point and approaches, economic structures and resources bases, the need to maintain strong and sustainable economic growth, available technologies and other individual circumstances, as well as the need for **equitable and appropriate contributions** by each of these Parties to the global effort regarding [the Convention's] objective". (emphasis added)[185]

It is not possible to state how "equitable" will be interpreted in this context, but the interpretation of Articles 4.6 and 4.10 which specifically mention factors relevant to developed country Parties will be particularly. The general principle of equity that "equity does not necessarily imply equality"[186] leaves open the possibility that in a dispute between developed country Parties, all Parties may not have to make equal contributions to the global effort.

This may have important consequences for the 35 developing country Parties plus the EC listed in Annex I of the Convention. In a dispute between developed country Parties, the application of equity to "excuse" one Party's failure to fulfil its obligations may have significant, adverse trade and competitiveness effects on the economy of a Party that had taken aggressive steps to fulfil the same obligations. The political compromise reached to group countries together

181 The full text of these articles is set out in the Annex.

182 See full text of Article 4.8. and 4.9 in the Annex.

183 *Id.* at art. 4.10, the text of which is set out in the Annex.

184 *See generally supra* notes 32–69 and accompanying text.

185 *Id.*

186 *Supra* note 174.

into three categories may therefore be completely undermined. On the other hand, Annex I includes countries and groupings with very different economic circumstances and challenges which it might be "inequitable" to ignore in the context of a particular case.

It is clear that equity must be applied in a legally fair, consistent and transparent manner between Annex I Parties. A failure to do so might undermine the Convention's existing allocation of rights and responsibilities between developed country Parties which, in respect of non-financial matters, impose the same legal commitment to protecting the climate. It will be important for the progressive development of the Convention to devise procedures so that the COP can indicate, in advance of formal legal disputes, how equity issues should be approached in a particular situation. Apart from the COP, which is the Convention's supreme decision body, its subsidiary bodies could also assist in this task. For example, the Multilateral Consultative Process, to be established under Article 13, could be asked to consider devising approaches to address this question.[187]

(iv) Lack of Proprietary Rights —Equitable Factors in Claiming Entitlements to the Climate System

Unlike UNGA Resolution 43/53 that initiated the international response to climate change, no mention is made in Article 3.1 to climate change being a "common concern of mankind".[188] This omission means that at least in the substantive parts of the Convention, there is no connotation of proprietary rights (communal or otherwise) so far as access or use of climate system or the atmosphere are concerned.[189]

This is so despite the fact that during the UNGA debate on the Resolution 43/53, the notion of "common concern" was preferred to "common heritage" precisely because it was considered not to have such proprietary connotations.[190] It is relevant to note that despite its lack of proprietorial connotations, all of the participants of UNEP's Legal Expert Group to consider the legal dimensions of the concept of common concern agreed that it involves "the equitable sharing of benefits or burdens".[191] In addition all agreed that the debate about the principle of common but differentiated responsibilities "relate[d] essentially to the sharing of costs and benefits of environmental protection".[192]

What is the legal basis for the allocation of benefits and burdens under the Convention? An alternative formulation of essentially the same question is: on what basis can Parties claim to be entitled to use the natural resources of the climate and what restrictions, if any, has the Convention provided to regulate such use? These questions remain central to the application of equity in the Climate Change Convention.[193]

The negotiating history of the Convention makes clear that delegations attending the first INC session in February 1991 had strong views about these questions which were reflected in their negotiating positions in the organisational and procedural matters discussed at that session.[194] The crux of the matter concerned the "main responsibility" principle, supported by developing countries during the negotiations, which attributes responsibility for climate change to developed countries on the basis that the largest share of emissions have originated in developed countries to support their own economic development and the over-consumptive lifestyles of their populations.[195] Developing countries stressed the concept of entitlement to GHGs emissions being distributed on a per capita basis.[196] For example, China's Non-Paper provided that:

> "Any limitation or control measures shall take full account of the per capita emissions levels of various countries and the developmental needs of developing countries".[197]

Developing countries' concept of equity linked together main responsibility, overconsumption,

[187]For a detailed examination of how this process might work, and its contribution to the implementation of the Convention see Jake Werksman, "Designing a Compliance System for the United Nations Framework Convention on Climate Change", Chapter 2, FIELD Report on Improving Compliance with International Agreements (forthcoming).

[188]UNGA Resolution 43/53 on "Protection of Global Climate for Present and Future Generations of Mankind" (6 December 1988) stated that the climate was a "common concern of mankind". The Resolution did not accept the language initially proposed by Malta that the climate be considered a "common heritage of mankind" which in the context of UNCLOS has distinct proprietorial implications.

[189]The common concern principle is reiterated, in a gender neutral manner, in the Climate Change Convention at paragraph 1 of the Preamble which is not legally binding.

[190]*Supra* note 134; See also Bodansky, *supra* note 96, at p. 465.

[191]*Id.* Some experts regarded the burden sharing "as an important subsidiary principal instrumental in the application of the common concern of mankind" whilst for others, "the very concept... would ultimately depend on the recognition or acceptance of equitable sharing of burdens".

[192]*Id.*

[193]For a thorough examination of these equity issues from an economic perspective, see Michael Grubb, *UNCTAD Study on Tradeable Permits*, New York.

[194]See Jacob Werksman, *The Negotiating History of the Climate Change Convention*, (unpublished manuscript on file with author).

[195]See for example, Paper No. 17, Non-Paper submitted by the Chinese Delegation to INC 1 in Compilation of Possible Elements for a Framework Convention on Climate Change. Doc. A/AC.237/Misc.2/Rev.1, 20 June 1991.

[196]See, Paper No. 15, Non-Paper submitted by the Indian Delegation to INC 2, Doc. A/AC.237/Misc.1/Add.3, 17 June 1991.

[197]*Id.*; The Indian submission proposed a strategy to achieve long term stabilisation "on the basis of an equitable formula requiring, *inter alia*, that anthropogenic emissions...should converge at a common per capita level, and that would take into account net carbon dioxide emissions during this century".

per capita emission levels and taking past emissions into account for calculating future entitlements. By contrast, developed countries concept of equity denied the relevance of these elements, stressing instead their greater responsibilities on the basis of their greater resources or "capabilities", and linking equity considerations with those relating to "cost-effectiveness".[198] For example, Norway's Non-Paper, on mechanisms to allocate global targets, provided that:

> "[m]easures to counter climate change should be environmentally efficient, equitable and cost-effective".

Neither side was successful in enshrining its concept of equity into the main body of the Convention's text. It is not clear therefore what the legal basis for entitlements to emissions of GHGs will be under the Convention. The Preamble refers to elements of the main responsibility principle and the relevance of per capita emission entitlements, whilst the concept of global environmental cost-effectiveness can be found in Article 3.3 in the overall context of the precautionary approach.[199] Thus whilst the main body of the Convention appears to be neutral on the question of entitlements and proprietary rights to the use of the climate system, the Preamble and Article 3 do contain references to both concepts of equity which could have significant legal consequences.

One relevant question is whether the references in the Preamble and Article 3 will prove sufficient to allow a Court or tribunal to establish the legal basis for entitlements to GHG emissions. In this regard, it is worth recalling that one of the principles of equity discussed by the ICJ in the continental shelf cases was that equity could be used to delimit areas but not to apportion continental shelf resources between States as the Court was not prepared to use equity to "share out something held in undivided shares".[200] The question in the case of the Climate Change Convention is whether, by virtue of its provisions, the climate system is "something held in undivided shares" or whether, as a result of its provisions, Parties have implicitly established a basis for entitlements to the use of the climate system.

In relation to this question, it is important to recognise that international law has allowed a State to establish preferential rights to fisheries, a natural resource that is otherwise a common, limited resource, where another State has recognised that State's long-established use and its particular economic dependence on that resource.[201] Whilst the law concerning the allocation of fisheries cannot be transposed to the climate change context, it is conceivable that the general principles of equity could be invoked to justify developed countries' use of the climate system at present day rates, particularly in the absence of developing countries' challenges to such use.[202] An important general equitable principle in this regard is the principle of "estoppel" which according to Tom Franck "imposes a duty on States to refrain from engaging in inconsistent conduct vis-a-vis other States".[203] A failure to address and challenge explicitly the global basis of entitlements to GHG emissions could be characterised as acceptance of current use levels and have significant legal implications for establishing a basis of entitlements to GHG emissions under the Convention.

D. Conclusions and Practical Recommendations

The purpose of this paper was to examine the role of equity in international environmental legal agreements and cases with a view to discussing their relevance to the implementation and developments of Parties' rights and obligations under the Convention to protect the climate system. The analysis of the nature and role of equity in Part A concluded that the application of equity in one dispute context cannot be transposed wholesale to another as it ultimately depends on the specific context of each case. This is especially relevant to the Climate Change Convention which creates a legal framework with its own principles and rules for deciding which factors or circumstances may be relevant to the application of equity in disputes between its Parties.

The examination of equity in a range of international environmental disputes concerning natural resources indicated in Part B however, that some general principles of equity may be relevant to the climate change context. These include in particular, the following principles:

- equity does not involve distributive justice;
- equity cannot compensate for the inequalities of nature;
- equity does not necessarily imply equality;
- equity requires the consideration of all relevant factual and legal considerations;
- equity implies a duty on States to refrain from

[198]Paper 14.3, Non-Paper submitted by the Norwegian submission to INC 2, Doc. A/AC. 237/Misc.1/Add. 2, 10 June 1991.

[199]Climate Change Convention, *supra* note 2, at Preambular paragraphs 3 and 18.

[200]See supra notes 45–47 and accompanying text concerning the *North Sea Continental Shelf Cases* and the *Gulf of Maine* case.

[201]*See e.g., Fisheries Jurisdiction case (Iceland/United Kingdom), ICJ Rep.* 1972, p. 16, para. 23.

[202]The relevant principle of equity is that of estoppel which according to Tom Franck "imposes a duty on States to refrain from engaging in inconsistent conduct vis-a-vis other States". *See* Frank and Sughrue, *supra* 9, for examples of the application of this principle.

[203]*Id.*

engaging in inconsistent conduct vis-a-vis other States; and

- equity entails the principle of good faith that requires States to enter into bona fide negotiations to resolve their differences.

This last principle may be of critical importance in the context of the Climate Change Convention which is a framework convention that provides a legal process, consisting of institutions and procedures, to resolve disputes between Parties concerning the interpretation and application of equity. The importance of the process established by the Convention cannot be overemphasised.

Whilst the Convention's provisions on principles attempt to provide a basis for guiding the Parties in the resolution of their disputes, the nature, legal status and meaning of the principles themselves indicate a need for Parties to engage in continual, constructive dialogue and good faith negotiations. As the case law of the ICJ makes clear, where differences of views exist, equity itself requires such good faith negotiations. The speed with which the Climate Change Convention was negotiated meant that many fundamental issues could not be addressed or conclusively resolved in the timetable imposed by UNCED. Further negotiations are vital if Parties are to resolve their differences in the interpretation, implementation and further development of their rights and obligations to protect the climate system in an equitable manner.

Third party dispute settlement by the ICJ or an arbitration body established under Article 14 may provide some clarification about the application of equity to some of the questions and issues outlined in Part C concerning the following:

- the implementation and enforcement of common responsibilities;
- the allocation of differentiated rights and responsibilities between present and future generations;
- the allocation of differentiated rights and responsibilities between members of the present generation represented by State Parties to the Convention; and
- the basis of legal entitlement for limiting use of the climate system which can be seen as a common and valuable natural resource.

A practical determination of these questions rests ultimately with the Convention's COP. Its decisions about these matters will depend, in part, upon the quality and relevance of the scientific and technological advice it receives from the IPCC and/or the Subsidiary Body for Scientific and Technological Advice established under Article 9.

As will have become clear from the above, the application of equity requires the consideration of all factual circumstances, including technological and scientific ones, considered legally relevant to a particular question. The IPCC can play a critical role in providing information about these factual circumstances. Initial clarification of the factual circumstances that the IPCC considers might be relevant, through for example, drawing up an indicative list of such considerations for a particular question, could certainly assist the COP in its decision. The general approach that should be taken could also be examined by the Multilateral Consultative Process to be established under Article 13.

It is ultimately for the COP to decide what the relevant factual circumstances are bearing in mind that it must be guided by the Convention's legal provisions as to what is or is not relevant. As far as clarification of what principles or considerations might be legally relevant, legal clarification by the ICJ or an arbitration panel could certainly assist a better understanding of these questions and issues. In the absence of a formal dispute however, the COP could seek legal advice from the ICJ about the interpretation of the Convention's "equity" provisions by requesting a competent international organisation to ask the ICJ for an advisory opinion.[204]

[204]Under Article 65(1) of the ICJ Statute, the ICJ can give an advisory opinion on any legal question requested by any body authorised by the UN including its specialised organs and agencies. This procedure has been used many times. Brownlie, *supra* note 10. Most recently, an advisory opinion was requested by the World Health Organisation concerning questions relating to the legality of nuclear weapons. *See* World Health Organisation (WHO) Resolution WHA 46.40.

ANNEX

Excerpts From the Framework Convention on Climate Change (1992)

Article 2
Objective

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Article 3
Principles

In their actions to achieve the objective of the Convention and to implement its provisions, the Parties shall be guided, *inter alia*, by the following:

1. The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.
2. The specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, and of those Parties, especially developing country Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration.
3. The Parties should take precautionary measures to anticipate, prevent and minimise the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account the policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.
4. The Parties have a right to, and should, promote sustainable development. Policies and measures to protect the climate system against human-induced change should be appropriate for the specific conditions of each Party and should be integrated with national development programmes, taking into account that economic development is essential for adopting measures to address climate change.
5. The Parties should cooperate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties, particularly developing country Parties, thus enabling them better to address the problems of climate change. Measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable dissemination or a disguised restriction on international trade.

Article 4
Commitments

2. The developed country Parties and other Parties included in Annex I commit themselves specifically as provided for in the following:

   (a) Each of these Parties shall adopt national[1] policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse sinks and reservoirs. These policies and measures will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention, recognising that the return by the end of the present decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol would contribute to such modification, and taking into account the differences in these Parties' starting points and approaches, economic structures and resource bases, the need to maintain strong and sustainable economic growth, available technologies and other individual circumstances, as well as the need for equitable and appropriate contributions

[1]This includes policies and measures adopted by regional economic integration organisations.

by each of these Parties to the global effort regarding that objective. These Parties may implement such policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention and, in particular, that of this subparagraph;

6. In the implementation of their commitments under paragraph 2 above, a certain degree of flexibility shall be allowed by the Conference of the Parties to the Parties included in Annex I undergoing the process of transition to a market economy, in order to enhance the ability of these Parties to address climate change, including with regard to the historical level of anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol chosen as a reference.
7. The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology and will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties.
8. In the implementation of the commitments of this Article, the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures, especially on:
   (a) small island countries;
   (b) countries with low-lying coastal areas;
   (c) countries with arid and semi-arid areas, forest areas and areas liable to forest decay;
   (d) countries with areas prone to natural disasters;
   (e) countries with areas liable to drought and desertification;
   (f) countries with areas of high urban atmospheric pollution;
   (g) countries with areas with fragile ecosystems, including mountainous ecosystems;
   (h) countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products; and
   (i) land-locked and transit countries.

Further, the Conference of the Parties may take actions, as appropriate, with respect to this paragraph.

9. The Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology.
10. The Parties shall, in accordance with Article 10, take into consideration in the implementation of the commitments of the Convention the situation of Parties, particularly developing country Parties, with economies that are vulnerable to the adverse effects of the implementation of measures to respond to climate change. This applies notably to Parties with economies that are highly dependent on income generated from the production, processing and export, and/or consumption of fossil fuels and associated energy-intensive products and/or the use of fossil fuels for which such Parties have serious difficulties in switching to alternatives.

Article 11
Financial Mechanism

2. The financial mechanism shall have an equitable and balanced representation of all parties within a transparent system of governance.

Excerpts From the Biological Diversity Convention (1992)

Preamble

Recognising the close and traditional dependence of many indigenous and local communities embodying traditional lifestyles on biological resources, and the desirability of sharing **equitably** benefits arising from the use of traditional knowledge, innovations and practices relevant to the conservation of biological diversity and the sustainable use of its components.

Recognising that economic and social development and poverty eradication are the first and overriding priorities of developing countries.

Article 1
Objectives

The objectives of this Convention, to be perused in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the **fair and equitable** sharing of the benefits arising out of the utilisation of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and technologies, and by appropriate funding.

Article 8
In-Situ *Conservation*

Each contracting Party shall as far as possible and as appropriate:

(j) Subject to its national legislation, respect, preserve, and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the **equitable sharing** of the benefits arising from the utilisation of such knowledge, innovations and practices;

Article 15
Access to Genetic Resources

7. Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, and in accordance with Articles 16 and 19 and, where necessary, through the financial mechanism established by Articles 20 and 21 with the aim of sharing in a **fair and equitable** way the results of research and development and the benefits arising from commercial and other utilisation of genetic resources with the Contracting Party providing such resources. Such sharing shall be upon mutually agreed terms.

Article 19
Handling of Biotechnology and Distribution of its Benefits

2. Each Contracting Party shall take all practicable measures to promote and advance priority access on a **fair and equitable** basis by Contracting Parties, especially developing countries, to the result and benefits arising from biotechnologies based upon genetic resources provided by those Contracting Parties. Such access shall be on mutually agreed terms.

Statute of the International Court of Justice (1945)

Art. 38 1. The Court, whose function is to decide in accordance with international law such disputes as are submitted to it, shall apply;

(a) international conventions, whether general or particular, establishing rules expressly recognised by the contesting states;
(b) international custom, as evidence of a general practice accepted as law;
(c) the general principles of law recognised by civilised nations;
(d) subject to the provisions of Article 59, judicial decisions and the teachings of the most highly qualified publicists of the various nations, as subsidiary means for the determination of rules of law.

Principle 2 of the Rio Declaration on Environment and Development (1992)

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

Principle 21 of the Declaration of the UN Conference on the Human Environment (1973)

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

ILC Draft Articles of the Non-Navigational Uses of International Waters (Part II)

General Principles

Article 5
Equitable and Reasonable Utilisation and Participation

1. Watercourse States shall in their respective territories utilise an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be used and developed by watercourse States with a view to attaining optimum utilisation thereof and benefits therefrom consistent with adequate protection of the watercourse.
2. Watercourse States shall participate in the use, development and protection of an international watercourse in an equitable and reasonable manner. Such participation includes both the right to utilise the watercourse and the duty to cooperate in the protection and development thereof, as provided in the present articles.

Article 6
Factors Relevant to Equitable and Reasonable Utilisation

1. Utilisation of an international watercourse in an equitable and reasonable manner within the meaning of Article 5 requires taking into account all relevant factors and circumstances, including:
   (a) geography, hydrographic, climate, ecological and other factors of a natural character;
   (b) the social and economic needs of the watercourse States concerned;
   (c) the effects of the use or uses of the watercourse in one watercourse State on other watercourse States;
   (d) existing and potential of watercourse;
   (e) conservation, protection, development and economy of the use of water resources of the watercourse and the costs of measures taken to that effect;
   (f) the availability of alternatives, of corresponding value, to a particular planned or existing use.
2. In the application of Article 5 of paragraph 1 of this article, watercourse States concerned shall, when the need arises, enter into consultations in a spirit of cooperation.

Article 7
Obligation not to Cause Appreciable Harm

Watercourse States shall utilise an International watercourse in such a way as not to cause appreciable harm to other watercourse States.

Article 8
General Obligation to Cooperate

Watercourse States shall cooperate on the basis of sovereign equality, territorial integrity and mutual benefit in order to attain optimal utilisation and adequate protection of an international watercourse.

Excerpts From United Nations Convention on the Law of the Sea (1982)

Part VI
Continental Shelf

Article 76
Definition of the Continental Shelf

1. The continental shelf of a coastal State comprises the sea-bed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.
2. The continental shelf of a coastal State shall not extend beyond the limits provided for in paragraphs 4 and 6.
3. The continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the sea-bed and subsoil of the shelf, the slope and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof.
4. (a) For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either:
      (i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope; or
      (ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope.
   (b) In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.
5. The fixed points comprising the line of the outer limits of the continental shelf on the sea-bed, drawn in accordance with paragraph 4(a) (i) and (ii), either shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or shall not exceed 100 nautical miles from the 2,500 metre isobath, which is a line connecting the depth of 2,500 metres.

Article 82
Payments and Contributions with Respect to the Exploitation of the Continental Shelf Beyond 200 Nautical Miles

1. The coastal State shall make payments or contributions in kind in respect of the exploitation of the non-living resources of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.
2. The payments and contributions shall be

made annually with respect to all production at a site after the first five years of production at the site. For the sixth year, the rate of payment or contribution shall be 1 per cent of the value of volume of production at the site. The rate shall increase by 1 per cent for each subsequent year until the twelfth year and shall remain at 7 per cent thereafter. Production does not include resources used in connection with exploitation.

3. A developing State which is a net importer of a mineral resource produced from its continental shelf is exempt from making such payments or contributions in respect of that mineral resource.
4. The payment or contributions shall be made through the Authority, which shall distribute them to States Parties to this Convention, on the basis of equitable sharing criteria, taking into account the interests and needs of developing States, particularly the least developed and the land-locked among them.

Article 83
Delimitation of the Continental Shelf Between States With Opposite or Adjacent Coasts

1. The delimitation of the continental shelf between States with opposite or adjacent coasts shall be affected by agreement on the basis of internatioal law, as referred to in Article 38 of the Statute of the International Court of Justice, in order to achieve an equitable solution.
2. If no agreement can be reached within a reasonable period of time, the States concerned shall resort to the procedures provided for in Part XV.
3. Pending agreement as provided for in paragraph 1, the States concerned, in a spirit of understanding and cooperation, shall make every effort to enter into provisional arrangements of a practical nature and, during this transitional period, not to jeopardise or to hamper the reaching of the final agreement. Such arrangements will be without prejudice to the final delimitation.
4. Where there is an agreement in force between the States concerned, questions relating to the delimitation of the continental shelf shall be determined in accordance with the provisions of the agreement.

UN Convention on the Law of the Sea

Part XI
The Area

Section 1. General Provisions

Article 133
Use of Terms

For the purposes of this Part:

(a) "resources" means all solid, liquid or gaseous mineral resources *in situ* in the Area at or beneath the sea-bed, including polymetallic nodules;
(b) resources when recovered from the Area, are referred to as "minerals".

Section 2. Principles Governing the Area

Article 136
Common Heritage of Mankind

The area and its resources are the common heritage of mankind.

Article 137
Legal Status of the Area and its Resources

1. No State shall claim or exercise sovereignty or sovereign right over any part of the area or its resources, nor shall any State or natural juridical person appropriate any part thereof. No such claim or exercise of sovereignty or sovereign rights nor such appropriation shall be recognised.
2. All rights in the resources of the Area are vested in mankind as a whole, on whose behalf the Authority shall act. These resources are not subject to alienation. The minerals recovered from the Area, however, may only be alienated in accordance with this Part and the rules, regulations and procedures of the Authority.
3. No State or natural or juridical person shall claim, acquire or exercise rights with respect to the minerals recovered from the Area in accordance with this Part. Otherwise, no such claim, acquisition or any of such rights shall be recognised.

Article 138
General Conduct of States in Relation to the Area

The general conduct of States in relation to the Area shall be in accordance with the provisions of this Part, the principles embodied in the Charter of the United Nations and other rules of international law in the interests of maintaining peace and security and promoting international cooperation and mutual understanding.

Article 139
Responsibility to Ensure Compliance and Liability for Damage

1. States Parties shall have the responsibility to ensure that activities in the Area, whether carried out by States Parties, or State enterprises or natural or juridical persons which possess the nationality of States Parties or are effectively controlled by them or their nationals, shall be carried out in conformity with this Part. The same responsibility applies to international organisations for activities in the Area carried out by such organisations.
2. Without prejudice to the rules of international law and Annex III, Article 22, damage caused by the failure of a State Party or international organisation to carry out its responsibilities under this Part shall entail liability; States Parties or international organisations acting together shall bear joint and several liability. A State Party shall not however be liable for damage caused by any failure to comply with this Part by a person whom it has sponsored under Article 153, paragraph 2 (b), if the State Party has taken all necessary and appropriate measures to secure effective compliance under Article 153, paragraph 4, and Annex III, Article 4, paragraph 4.
3. State Parties that are members of international organisations shall take appropriate measures to ensure the implementaion of this article with respect to such organisations.

Article 140
Benefit of Mankind

1. Activities in the Area shall, as specifically provided for in this Part, be carried out for the benefit of mankind as a whole, irrespective of the geographical location of States, whether coastal or land-locked, and taking into particular consideration the interests and needs of developing States and of peoples who have not attained full independence or other self-governing status recognised by the United Nations in accordance with General Assembly resolution 1514 (xv) and other relevant General Assembly resolutions.
2. The Authority shall provide for the equitable sharing of financial and other economic benefits derived from activities in the Area through any appropriate mechanism, on a non-discriminatory basis, in accordance with Article 160, paragraph 2 (f) (i).

Geneva Convention on the Continental Shelf (29 April 1958)

The State Parties to this Convention have agreed as follows:

Article 1

For the purpose of these articles, the term "continental shelf" is used as referring (a) to the sea-bed and subsoil of the submarine areas adjacent to the coast but outside the area of territorial sea, to a depth of 200 metres or, beyond that limit, to where the depth of the superjacent waters admits of the exploitation of the natural resources of the said areas; (b) to the sea-bed and subsoil of similar submarine areas adjacent to the coasts of islands.

Article 2

1. The coastal State exercises over the continental shelf sovereign rights for the purpose of exploring it and exploiting its natural resources.
2. The rights referred to in paragraph 1 of this article are exclusive in the sense that if the coastal State does not explore the continental shelf or exploit its natural resources, no one may undertake these activities, or make a claim to the continental shelf, without the express consent of the coastal State.
3. The rights of the coastal State over the continental shelf do not depend on occupation, effective or notional, or on any express proclamation.
4. The natural resources referred to in this article consist of the mineral and other non-living resources of the sea-bed and subsoil together with living organisms belonging to sedentary species, that is to say, organisms which, at the harvestable stage, either are immobile on or under the sea-bed or are unable to move except in constant physical contact with the sea-bed or the subsoil.

Article 3

The rights of the coastal State over the continental shelf do not affect the legal status of the superjacent waters as high seas, or that of the airspace above those waters.

Article 4

Subject to its rights to take reasonable measures for the exploration of the continental shelf and the exploitation of its natural resources, the coastal State may not impede the laying or maintenance of submarine cables or pipelines on the continental shelf.

Article 5

1. The exploration of the continental shelf and the exploitation of its natural resources must not result in any unjustifiable interference with navigation, fishing or the conservation of the living resources of the sea, nor result in any interference with fundamental oceanographic or other scientific research carried out with the intention of open publication.
2. Subject to the provisions of paragraphs 1 and 6 of this article, the coastal State is entitled to construct and maintain or operate on the continental shelf installations and other devices necessary for its exploration and the exploitation of its natural resources, and to establish safety zones around such installations and devices and to take in those zones measures necessary for their protection.
3. The safety zones referred to in paragraph 2 of this article may extend to a distance of 500 metres around the installations and other devices which have been erected, measured from each point of their outer edge. Ships of all nationalities must respect these safety zones.

Equity in an International Agreement on Climate Change

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Equity Under a Global Emissions Ceiling

Fundamental Fairness

What diplomats and lawyers tend to call "equity" incorporates important aspects of what ordinary people everywhere call "fairness". The concept of fairness is neither Eastern nor Western, neither Northern nor Southern, but completely universal. People everywhere understand what it means to ask whether an arrangement is fair or is instead biased toward some parties over other parties. If you own the land but I supply the labour, or you own the seed but we own the ox, or you are old but we are young, or you are female but I am male, or you have an education and I do not, or you worked long and hard but I was lazy—in situation after situation it makes perfectly good sense to ask whether a particular division of something among two or more parties is fair to all the parties, in light of this or that difference between the parties. All people understand the question, even where they have been taught not to ask it. Should the educated be paid more than the uneducated (and if so, how much)? Should hard workers be paid more than the lazy (and if so, how much)? What about the educated but lazy *versus* the uneducated but hard working? What would be fair? Or, as the lawyers and diplomats would put it, which arrangement would be equitable?

Ultimate Scarcity

Adoption of a global ceiling on greenhouse-gas (GHG) emissions will radically transform the international context for fairness. Three levels need to be noted: science, policy, and equity, or fairness. The scientific investigations reported by the IPCC provide a solid basis for the conclusion that there is in fact a *natural limit* on the GHG emissions that this planet can process without rises in surface temperature (and other complex and mostly unwelcome climate change). If the science is correct, the natural limit exists whether we choose to acknowledge it or not. If, at the level of policy, we acknowledge the natural limit and attempt to protect ourselves against the unwanted effects of exceeding the limit, we will act under the *Framework Convention on Climate Change* to impose on GHG emissions a *global ceiling*. While the natural limit on the earth's capacity to handle anthropogenic additions in excess of natural emissions is a given, the global ceiling would be a political limit that we imposed upon ourselves. If we wish to protect ourselves against the untoward (for us) natural effects of limitless increases in anthropogenic GHG emissions, we may have no good alternative to the adoption of a global ceiling. Nevertheless, the adoption of a global ceiling is a political choice of policy, and we are responsible for the effects of the policies we adopt, most of all the effects on those powerless to influence our choices.

A political decision to adopt a global ceiling on GHG emissions has implications for equity that are far more radical than has so far been recognised. A serious decision to deal with the natural limit on the planet's capacity to dispose of GHG emissions by imposing a political limit on the emissions produced by humans totally transforms the international situation. The reason is simple: imposition of an emissions ceiling makes emissions, as the economists like to say, *zero-sum*. For equity this change has powerful implications. First, we should review the meaning of "zero-sum", which is widely understood; then, we can see the significance of making a quantity zero-sum, which is so far less widely understood.

A total is zero-sum if more of it for anyone means less of it for everyone else. A total that is zero-sum is a total that cannot be enlarged. If there is +3 for you, there must be -3 for the rest of us; the sum is always zero: +3 and -3 are zero. Consequently, each time that some of whatever is in question is used by someone, less of it is left for all the others. Establishing a global ceiling on GHG emissions makes GHG emissions zero-sum. Since the total cannot be increased, because a ceiling has been placed on the total, each unit of emissions used up by one party will be a unit not available for use by all the other parties. This much, the definition of "zero-sum", is obvious and undeniable.

What is the significance for equity of a policy that makes emissions zero-sum? Once a total is zero-sum, anyone who consumes more than her own share harms others whose share she thereby takes away. Over-consumption is encroachment.[1] In the consumption of anything the total of which is to be kept zero-sum, there is no such thing as "a little harmless over-indulgence". Once one has used up one's own share, continuing to consume is always using up someone else's share, provided only that the case is one in which there are fair shares.[2] One is doing harm to the person whose share one is consuming, because one is depriving the other person of the only share she could have had (without her in turn depriving some third person). Over-consumption—that is, use of more than one's share—always wrongs someone once a total has become zero-sum. Over-consumption is no longer, if ever it was, a victimless crime. Those for whom the supply of something important is zero-sum face the ultimate scarcity: one cannot exceed one's share without doing wrong. In a zero-sum context, other people are always affected by consumption in excess of one's own share. There is no slack, in fact—or in equity.

It is also undeniable, I think, that creating the ultimate scarcity of a zero-sum total has the significance for equity just indicated. However, this fundamental implication for equity may not be obvious and so it may be worth illustrating it in a different case. Suppose I very much enjoy dining and I can afford to buy as much food as I like. Yet there are many malnourished, hungry people in the world. Whatever money I spend on food for myself that I enjoy but do not need to eat, is money that I could instead have spent providing desperately needed food to some number of persons who do not have enough. Now, people disagree about the ethics of a case like this. Some people believe that once you have enough for yourself, you ought then to assist others in obtaining what they need, before you go on to enjoy luxuries, even if their need is in no degree your fault. These people believe that it is selfish to indulge yourself when others lack necessities. Other people, by contrast, think that as long as you are minding your own business and not doing others any harm, you are not morally required to provide any positive assistance to others that you do not choose to provide (although it is certainly admirable to choose voluntarily to help in ways not required).

The ethical debate just sketched is about the extent to which any one human being is required to help other human beings in need. The answers normally defended range across a wide spectrum between the one extreme, no help is required (although it is praiseworthy to volunteer it anyway), to the other extreme, as much help as possible is required once one's own needs are satisfied. It would be irrelevant to the subject at hand to pursue this issue, although it is widely discussed and important in its own right. I have mentioned this other debate here strictly in order to note one of the crucial features of the circumstances it assumes, namely it is entirely about whether to offer help to someone for whose plight one bears no causal responsibility. The question there is: How much responsibility does one have to help someone whom one has not harmed? Ought I to help a complete stranger to whom I have done no harm?

It is a very different matter if I have in fact wronged the person whose plight is under consideration—if that person's plight was caused by harm that I did. The question, ought I now to help someone whose need for this help results from harm that I myself inflicted? is radically different from the question, ought I to help a stranger whom I have never harmed? And the reason that the situation is so different when harm has been done is that one of the most basic principles of equity in every culture about which I know—and I hope any significant counter-examples will be brought to my attention—is: Do no harm. One may or may not be expected to help in this or that context, but one is always expected not to harm (but for exceptional overriding circumstances). Consequently, the obligation to restore those whom one has harmed is acknowledged even by those who reject any general obligation to help strangers. Whatever one's obligation to help people with whom one has no previous connection, one virtually always ought to "make whole," insofar as possible, anyone whom one has harmed. And this is because one ought even more fundamentally to do no harm in the first place.

Now it should be clearer why the adoption of a global ceiling on GHG emissions so radically transforms the international context for equity. In the absence of a ceiling on total emissions, some party might out of goodwill volunteer to refrain from excessive emissions as a gesture of helpfulness to other parties.[3] Or it might not. With the ceiling in place a party that does not refrain from excessive emissions—meaning emissions in excess of its own fair share of the total—is, far

[1] I previously argued that in this new context "*excess encroaches*" in Henry Shue, "After You: May Action by the Rich be Contingent Upon Action by the Poor?" *1 Indiana Journal of Global Legal Studies* (1994), 343, at 364.

[2] I explain below why questions of fairness arise in the case of GHG emissions, although I think the reasons are actually quite obvious.

[3] I am assuming, merely for the sake of argument, that there are no other independent grounds for thinking that emissions already ought to be restricted . That is far from clear, but I simply want to concentrate on one line of argument at a time.

from simply not volunteering to help, inflicting harm. Using up emissions that in equity belong to another party constitutes the doing of harm to that other party. People have different views about when, if ever, one is obligated to help strangers, but I have not yet encountered anyone who was prepared seriously to defend the view that one is free to inflict harm on strangers.

After the adoption of a global ceiling, volunteering to help will consist only in volunteering to consume less than one's equitable share. Consuming no more than one's share will have become subject to what may be the most fundamental principle of equity of all: Do no harm. The adoption of a ceiling on total emissions moves the consumption of more than one's share of allowable emissions into a new category of equity, the category of rock-bottom prohibited wrong.

Fair Shares

If a party's exceeding its fair share will be a fundamental wrong, it becomes exceedingly important how fair shares are determined. But isn't the question of the appropriate standards for allocating fair shares one of those eternal enigmas, endlessly debated but never settled? No, it is not. I next want to suggest that the problem of specifying fair shares is actually much easier than it may seem. First, we should quickly remind ourselves of one purely contingent but for now unavoidable feature of the world economy.

It happens that at present a considerable quantity of GHG emissions in the form of CO_2 are a necessity for any decent human life. This does not need to be the case and presumably will not always be the case. CO_2 emissions are as vital as they are now only because the particular form of industrialisation created by the now-industrial societies rests upon a fossil-fuel energy regime. As long as industrial activity is dependent upon fossil-fuel, which is of course carbon-based, the industrial activity necessary for a modestly adequate standard of living will generate large quantities of CO_2, a GHG with an especially long atmospheric-residence time. Of the people in the world, more than 99.9999% have had absolutely no voice in the adoption or the dogged retention of the energy regime of fossil-fuel into which they are simply born. Whenever we can advance beyond dependency upon fossil-fuel, anthropogenic CO_2 emissions may become of little consequence and even less interest. Meanwhile, the current global energy regime makes CO_2 emissions central and vital.

Given a global ceiling on total GHG emissions, how do we calculate national shares? Equity in shares begins at the bottom—with those whose actual shares are smallest. (Those who already have large shares do not normally need to appeal to others to treat them fairly.) The first concern of equity is with the minimum share. Every national share of the global total must be at least enough for every person in the nation to lead at least a minimally decent life.[4] Why?

Obviously a philosophically adequate theoretical explanation would require considerably more scope than a single paper and would venture beyond present concerns. Brief remarks can, however, be made at two levels of abstraction. At the more abstract level it is evident that the notion of human equality is meaningless unless it entails that there is something—and of course not necessarily only one thing—to which all human beings are equally entitled. If an assertion of human equality did not mean that something must be kept equal among human beings, it is not apparent what it could mean. It would presumably be empty, misleading rhetoric.

At a more concrete level, then, the question becomes: Which thing(s) must be guaranteed equally to all humans if we believe in human equality? Obviously many values central to human life are possible candidates for guaranteed equal distribution: opportunities (of various kinds), legal due process, wealth, health, liberties (of various kinds), cultural autonomy, economic development, healthy environment, physical safety, and much else. On the other hand, in many of these cases there are at least plausible reasons why it is not the best arrangement to have political institutions that centrally maintain an equal distribution of the value in question, however important it may be in itself. If one is interested, not in beautiful phrases but in serious policy, one must look in the case of each of these values in detail at the advantages and disadvantages of specific institutions that could guarantee an equal distribution of the value in question. My own view, as I am sure is already obvious, is that some of the items listed should be guaranteed an equal distribution and some should not. Which so far tells you nothing, or almost nothing.

Once it is acknowledged, as I have just done, that even some important human values ought not to, or need not, be guaranteed an equal distribution, it becomes especially important to be careful about which views are, and which are not, categorised as "egalitarian". Most politically thoughtful people already have strong feelings for or against "egalitarianism", so that they react strongly one way or another to any view so labelled. Naturally, no one—and certainly not I—

[4] I want to emphasise that I am now discussing only the *minimum*. I am not implying that no one is entitled to anything but the minimum in saying that everyone is indeed entitled to the minimum. I have discussed this at greater length in *Basic Rights* (Princeton University Press, Princeton, NJ, 1980).

owns a copyright on the term "egalitarian" and people are free to define it as they think best, within reason. But because the term is so emotionally charged, and because politically important differences are in danger of being overlooked, I am simply urging caution. I would suggest reserving *egalitarian* for views specifying that equality ought to be enforced at levels well above minimum levels. The view that everyone is entitled to the same basic minimum, by contrast, is naturally referred to as an endorsement of a *guaranteed minimum.*

For example, the view that everyone has a right to literacy is embracing what I would call a guaranteed minimum of education. The view that everyone has a right to a university education is egalitarian. Similarly, endorsing free preventive health services (like immunisations against communicable diseases) for everyone is endorsing a guaranteed minimum, but advocating free surgery for everyone who could benefit from it is advocating egalitarianism. There is a sense in which literacy and a baccalaureate are different points on the same spectrum—education—and differ only in degree: One is less, and the other is more, education. Yet they are points that are so far apart that in most contexts it would be wildly misleading not to distinguish them. Similarly for vaccinations and operations. Accordingly, while it may not strictly speaking be an error to call an advocate of universal rights to literacy and immunisations an "egalitarian", that practice simply leaves one with no good name for the advocate of open universities and full national health services, which are what I would call full-bloodedly egalitarian measures.

Now, as I am sure has already become clear, I do not think that it is accurate or helpful to call those advancing the view that every person is entitled to a minimum level of GHG emissions an "egalitarian", irrespective of whether calling them that would make them more or less appealing to any particular other person. At this time, a human being is born into a world in which, because of the kind of industrial system that—for better or for worse—we in fact have, it is impossible to lead a decent life without benefiting from a minimum level of CO_2 emissions. CO_2 emissions are at present a vital necessity. As I have already mentioned, this could change. If we moved from a fossil-fuel regime to a solar regime, CO_2 emissions would become inessential. Meanwhile, they remain essential.

CO_2 emissions are, then, a necessity and, moreover, for everyone except those who actually control energy policies, an imposed necessity. No one, except the few who purposefully choose to cling to the fossil-fuel regime against less primitive technologies, chooses to lead a life that requires CO_2 emissions rather than a life that does not; all the ways of life available to the vast majority of humanity within the current energy regime require CO_2 emissions. This is the technological world every person inherits at birth. The dominance of this particular energy technology is one good reason why everyone ought to be guaranteed at least the minimum level of CO_2 emissions that the technology makes necessary to a decent life.

In sum, the argument actually has three steps. First, a commitment to human equality, which is not to be empty talk, requires that some aspects of life be equal for all persons. The question becomes: Which specifically? Second, the most plausible candidates in general to be the subjects of guaranteed equalities are necessities of life in circumstances in which people are unable to secure them for themselves. Necessities that are often impossible for people to provide for themselves include food (when, for example, there is disruption of agriculture by natural disaster or warfare), literacy, and vaccines. Many of us would argue that all such basic material necessities must be guaranteed equally to all who are powerless to obtain them for themselves—one simply displays contempt for the life of the helpless who are excluded from such social arrangements.[5] Third, the position is stronger still in the case of what can be called avoidable necessities: what are in fact at this time necessary but would not be necessary if we chose to pursue different technology.[6] CO_2 emissions are a necessity of life only until we advance beyond fossil-fuel energy technology. The recent Australian "conceptual breakthrough" in solar technology makes photovoltaic, for example, an even more promising alternative than it already was.[7] Our technological choice of energy source has powerful implications for equity. If we make it impossible for people to lead a decent life without CO_2 emissions, we must in equity not actively prevent them from producing those minimum emissions.

Double Imposition

And that is precisely what we would do if, given our real current technological circumstances, we imposed a global ceiling on CO_2 emissions without protecting at least a minimum level of CO_2 emissions for every human being. A global ceiling on emissions at a stage in economic history when we are dependent upon fossil-fuel technology, unaccompanied by a firm

[5]See Shue, *Basic Rights*, ch. 5 .

[6]See Henry Shue, "Avoidable Necessity: Global Warming, International Fairness, and Alternative Energy", in *Theory and Practice*, edited by Judith Wagner DeCew and Ian Shapiro (New York University Press, New York, 1994).

[7]See Matthew L. Wald, "New Design Could Make Solar Cells Competitive", *New York Times*, 14 June 1994, p. C9. The story reports the work of Prof. Martin A. Green at the Center for Photovoltaic Devices and Systems, University of New South Wales.

guarantee for every person of a minimum level of emissions, would constitute a double imposition. On the one hand, we would impose a continuing fossil-fuel regime, when we could be moving to alternative regimes, thereby imposing the necessity of CO_2 emissions, and, on the other hand, we would impose a limit on emissions that did not allow everyone to have this necessity, if the shares of the limited total were not equitable. Here, as everywhere, equitable means: protection for an adequate minimum. An equitable emissions regime must, if it includes a limit upon the global total, guarantee a universal right to a minimum share of emissions. Otherwise, the limited total will be completely used up by a relative few. Minimum shares need protection against encroachment by over-consumers.

If ever there were, for example, the kind of system of tradeable emissions permits that economists like so much, the trading system would have to rest upon a foundation of inalienable—non-tradeable—permits securely guaranteeing a minimum level of emissions to every human being.[8] To fail to arrange for rights to minimum inalienable emissions would permit the infliction of serious harm—as explained above in "Ultimate Scarcity"—upon the people whose equitable share would as a result of that lack of protection be taken away from them through being used by others. In fact, whatever the particular scheme aimed at promoting efficiency—tradeable permits or other arrangements—the one feature demanded by equity in any international agreement imposing a global ceiling is protection for minimum shares.

An Alternative to International Agreement?

There may be no completely good solution to global warming, which is a serious and unprecedented problem. Even in the cases of simpler and less important problems, one often must choose the least bad option from among a bad lot because there is no good option. This means that options must almost always be assessed comparatively. Having seen a little of what equity can tell us about what international agreements ought to include, we might do well next to see what consideration of equity can tell us about the leading alternative, which seems to be something called "joint implementation."

Two preliminary clarifications. First, I say "something called 'joint implementation'" because it is my impression that exceedingly, and importantly, different schemes are being called, as I will henceforth for brevity style it, JI. I shall have much more to say about this presently. Second, what I am treating as two options, international agreement and JI, could be combined as one: an international agreement to allow and encourage specific forms of JI. Such agreed-upon JI would be a type of regulated, or at least guided, JI. When I refer to JI as an alternative to international agreement, I mean unregulated types of JI pursued ad hoc outside of any guiding framework specified by international agreement. Indeed, my main point about JI will be that various activities that might by their proponents be called "JI" differ so much from each other that it is essential that forms that deal effectively and equitably with global warming be encouraged and others be discouraged.

Conflicting Conceptions

Since one of the primary issues about JI is how to specify it and which untakings to treat as examples of it, it may clarify matters to begin with three ideal types; "ideal", not in the sense of supremely good, but in the sense of supremely simple. To maintain simplicity I shall in each of the three instances assume arbitrarily that electricity generation is the enterprise in question, although obviously many different kinds of activities might fit the three patterns I am about to sketch. The one essential element of all JI—the element that is the basis for calling what is done "joint"—is that an activity is performed in nation #1 by a firm that in some sense, which needs to be further specified, "belongs" to nation #2. Extremely different purposes can, however, be pursued.

Type 1: *Less-Cost Reduction.* Prior to the JI, an electricity-generating facility in nation #1 was producing *M* megawatts of electricity by emitting *E* tons of carbon. The JI consists of a firm from nation #2 building a new electricity generating facility in nation #1 that produces *N* megawatts of electricity [$N > M$] by emitting *D* tons of carbon [$D < E$]. The firm from nation #2 has enabled nation #1 to produce *more* electricity than before with *fewer* emissions. The firm has obviously delivered a superior technology. Whose property the technology is—whether it is sold, given, licensed, or what, and on what terms—is a supremely important issue, and it too is an issue of equity. However, issues about equity in technology transfer are relatively familiar and thoroughly aired, and JI does not raise them in any unique way, so I will not devote space to those equitable issues here.

JI_1, as I will call this, has two critical features. First, it *reduces* GHG emissions and thereby contributes positively to the mitigation of global warming. Second, it contributes positively to the standard of living in nation *#1*. Strictly speaking, it only directly increases the amount of electricity

[8] I have explained the necessity of underlying inalienable rights to minimum emissions more fully in Henry Shue, "Subsistence Emissions and Luxury Emissions", *Law & Policy*, vol. 15, no. 1 (January 1993), pp. 39–59.

available; and a nation can certainly waste electricity in such a way that the standard of living of its people is not raised, or its population growth can cancel out any potential per capita increases. However, these also are familiar and separable problems that I will not pursue here. My ideal types are designed to highlight other issues more integral to global warming.

The third feature that JI_1 has, by assumption, is that the firm from nation #2 can produce the reduction in emissions in nation #1 at less cost than any firm could produce a reduction of the same magnitude in nation #2. This must be added by assumption because the simple fact that a profit-seeking firm chose to conduct its activity in nation #1 rather than in nation #2 could have many explanations other than the costs being lower in nation #1—perhaps some source (inside or outside nation #1) was willing to pay to have the work done in nation #1 and no one was willing to pay to have it done in nation #2 even if nation #2 was not already generally using the technology in question. One could of course vary the case by assuming, not merely less cost, but globally least cost; again, there is obviously even less reason to assume this would happen automatically in an unregulated market.

Type 2: *Source-Sink Equivalence*. Something quite different is also referred to as "joint implementation". Here, prior to the JI, an electricity-generating facility in nation #2 was producing R megawatts of electricity by emitting J tons of carbon. The JI consists of a firm from nation #2 engaging in two activities: (a) building a new electricity-generating facility within nation #2 that produces S megawatts of electricity [$S > R$] by emitting K tons of carbon [$K > J$] and (b) introducing new carbon sinks into nation #1 that absorb ($K - J$) tons of carbon. The firm in nation #2 (a) has enabled nation #2 to produce *more* electricity than before but with *greater* emissions, while it also (b) has produced additional sinks (in nation #1) sufficient to eliminate any net increase in emissions. Altogether, the firm in nation #2 has enabled nation #2 to produce *more* electricity than before with the same net emissions, which is certainly an increase in one kind of efficiency.

JI_2, as I will call this, has two critical features, as did JI_1, but the features are very different. First, it leaves GHG emissions *unchanged* and thereby contributes nothing positive to the mitigation of global warming. Second, it contributes positively to the standard of living in nation *#2*. Theoretically, it could contribute to the standard of living in nation *#1* as well; if the carbon sink consisted of new forests and the most productive use of land in nation #1 happened to be for additional forest, nation #1 might benefit as well. This leaves, however, many unanswered questions, such as how the same land can both provide the maximum sustainable yield of lumber (to benefit nation #1) and provide sufficient carbon sinks (to enable nation #2 to avoid making GHG emissions worse by its increased production of electricity). One cannot help wondering how often everyone on both sides will be so fortunate as to find that the best carbon sinks from the perspective of nation #2 will just happen to be the most productive use of land from the perspective of nation #1. Obviously, if the firm paid nation #1 enough for the right to use the land as a sink, that rent could make this the most productive use of that land. Equally obviously, few poor nations have the leverage to strike such a fair deal. In any case, I will not stipulate whether the standard of living in nation #1 does or does not rise. The second feature of JI_2 is simply that the standard of living in nation *#2* does rise.

Type 3: *Less-Emission Increase*. Something else quite different yet is also being anointed as "joint implementation". Now, prior to the JI, an electricity-generating facility in nation #1 was producing M megawatts of electricity by emitting E tons of carbon (exactly as in JI_1). But in this instance the JI consists of a firm from nation #2 building a new electricity-generating facility in nation #1 that produces Q megawatts of electricity [$Q > M$] by emitting F tons of carbon [$F > E$]. The firm from nation #2 has enabled nation #1 to produce *more* electricity than before but with *greater* emissions. It is actually indeterminate from what I have said so far whether the new technology is more efficient—qualitatively better—or simply bigger in capacity. For the sake of the argument, however, assume that it is more efficient: Q/F is a better ratio than M/E.

Call this JI_3. Its two critical features are the following. First, it *increases* GHG emissions and thereby interferes with the mitigation of global warming. Second, it contributes positively to the standard of living in nation *#1*.

The critical features of these three ideal-types—obviously there are others—can be summarised as follows:

Three types of joint implementation	Emissions effects	Most likely rise in standard of living
JI_1	reduction	poor nation
JI_2	unchanged	rich nation
JI_3	increase	poor nation

If nothing else, I hope that it is now evident that very different enterprises are being denominated "joint implementation" and that it is vital for reasonable discussion to determine at least the very small amount of information that I have built into my three ideal-types before one tries to say whether something with this now-trendy name is good or bad.

Dubious Equity

More important, however, are the profound questions about equity that are raised by merely these three types of so-called JI—and above all, by their interactions if they are not coordinated under a framework agreement. A short paper does not provide scope for an adequate exploration of the full complexity of any of the implicated dimensions of equity. If serious analysis of the equity of "joint implementation" does not begin immediately, however, the headlong rush of practice will far outstrip careful reflection, not to mention intelligent control for the sake of the global environment.

Consider JI_3, to take only one example. Bearing in mind that the fundamental purpose of this whole exercise is to establish (at least) a global ceiling, one might initially think that JI_3, because it increases GHG emissions, ought to be discouraged in favour of JI_1, which reduces GHG emissions. Yet it is fairly obvious that whether an instance of JI_3 ought to be discouraged or not (a) cannot be determined in the abstract and (b) turns on equity. Whether an instance of JI_3 in nation *X* is on the whole good or bad depends upon whether *ex ante* the people of nation *X* have their fair share of the global total of emissions. If they do not have their fair share, instances of JI_3 may be exactly what they need. If they already have more than their share, JI_3 may simply contribute toward worsening global warming while making the world more inequitable.

In general, whether a specific nation should or should not increase its GHG emissions depends entirely upon whether its current share of GHG emissions is greater or less than its fair share. This simple finding, which I believe is difficult to controvert, has three powerful implications about JI as an alternative to international agreement, that is, about free-lance, unguided JI.

1. We need an agreed standard of equity before "joint implementation" is undertaken. Only *after* a standard of equity has been specified will it be possible to know whether a proposed instance of JI that would produce a net increase in emissions—like JI_3—is acceptable or unacceptable. Otherwise, the cause of preventing global warming will be damaged for no good reason by some JI, namely any JI that increases the share of a nation whose share is already too great, given the global ceiling and the GHG emission needs (as long as we continue with a fossil-fuel regime) of everyone else. It is irresponsible to tolerate everything that anyone wants to call "joint implementation".
2. We need effective mechanisms to encourage helpful JI and to discourage harmful JI, as assessed by the standard of equity.
3. We need effective mechanisms to produce compensating reductions in GHG emissions for all justified increases in GHG emissions, that is, for all increases in GHG emissions in nations that now have less than their fair share of the global total. On the one hand, for the sake of equity it is important that JI go forward in nations whose emissions are now below their reasonable share of the global total, at least where the increases will improve the lives of their own people.[9] On the other hand, for the sake of establishing a global ceiling it is important that net emissions not increase. Net increase can be avoided only if any increases in nations that are entitled in equity to greater emissions are cancelled out by reductions elsewhere, namely nations where current emissions exceed a fair share of the global total. To be responsible, any plans for JI that will increase emissions somewhere must also include a specification of where and how emissions will be decreased by the same amount.

In sum, equity requires that "joint implementation" not be accepted as a substitute for an international agreement that includes the three features listed. "Joint implementation" can be acceptable only within the framework of an international body to implement it. Uncontrolled JI—JI outside an agreed framework—is liable to deal with the difficult choices we face by taking the ever-popular route of avoiding painful redistribution by enlarging the pie. With a larger pie, those who now have less than enough can have more without taking anything away from those with more than their share. Unfortunately, our fundamental goal of a global ceiling on GHG emissions means that there can be no enlargement of the emissions pie. And that means that painful redistribution is the only conceivable route to greater equity, as long as we cling to the fossil-fuel regime that makes large GHG emissions essential to economic health. Decentralised and uncoordinated instances of "joint implementation" are incapable of solving the problem.

A wild wave of market fundamentalism is surging around the globe. "The Market" is being fervently preached as the solution to every problem. Market mechanisms do some jobs extremely well, and it is folly not to use them where they are best means to the end. Equitably preventing global warming is a special—indeed,

[9] Emissions increases on the territory of a nation obviously need not improve the welfare of the citizens of that nation. There is great danger that what is described as a firm from nation #2 building a new facility for nation #1 is simply nation #2 producing additional emissions for its own purposes from a platform in another nation's territory. These accounting problems arise equally for all schemes that involve national assignments of emissions, including schemes that ignore equity.

an extraordinary—case, and this mission cannot be accomplished without prior political choices to structure the incentives that market actors encounter. If we simply unleash firms to engage in whatever they choose to call "joint implementation", the result will be neither a global ceiling on total emissions nor an equitable distribution of the shares of whatever total there is. These are not goals to which one can get by purely market means. Incentives to maintain a global ceiling and incentives to distribute it equitably cannot arise spontaneously—they need to be put in place by international agreement. Otherwise, we will fail to prevent global warming, much less to accomplish it with equity.

Conclusion

The fundamental focus of equity is the protection of an adequate minimum for those unable to protect their own. This paper briefly touches upon equity under two options: international agreement upon an emissions ceiling and unregulated "joint implementation". The adoption of a global ceiling creates an urgent need for an adequate minimum share to be guaranteed to those who cannot take it for themselves. The acceptability of projects of "joint implementation," of which three highly divergent types are sketched, depends upon whether they increase the emissions of those who now have less than their fair share or those who already have more, as judged by equity. Consequently, "joint implementation" should not proceed without agreed background standards of equity.

The Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer: Lessons for Climate Change

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Introduction

1. This paper gives a preliminary assessment of the similarities and differences of some of the prominent features/provisions, including those that take into account equity and social considerations, of the Vienna Convention for the Protection of the Ozone Layer, the Montreal Protocol on Substances that Deplete the Ozone Layer and the United Nations Framework Convention on Climate Change (UNFCCC).

2. Based on the assessment, the paper attempts to highlight the features and mechanisms under the Vienna Convention and the Montreal Protocol that have not been utilised under the UNFCCC, but might be usefully applied in the future work on climate change envisaged under the UNFCCC.

Brief background

(a) The Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer

3. As concerns over the depletion of the ozone layer mounted during the mid-seventies UNEP was asked to coordinate a World Plan of Action on the ozone layer. A Coordinating Committee on the Ozone Layer (CCOL) consisting of representatives of Governments, organisations and chemical manufacturers was established to assist in the task. Several studies and assessments were carried out from 1977 and these formed the basis for the Convention for the Protection of the Ozone Layer adopted in Vienna in 1985. After two more years of intensive negotiations, the efforts to protect the ozone layer took a vital step forward with the adoption of the Protocol on Substances that Deplete the Ozone Layer in Montreal in September 1987.

4. The Vienna Convention entered into force on 22 September 1988 and the Montreal Protocol on 1 January 1989. The First Meeting of the Conference of the Parties to the Vienna Convention and the First Meeting of the Parties to the Montreal Protocol were held in Helsinki from 26 to 28 April 1989 and 2 to 5 May 1989, respectively. The Parties decided, *inter alia*, to designate UNEP as the Secretariat for the Vienna Convention and its Montreal Protocol. During these Meetings, 81 Governments that were present adopted the Helsinki Declaration on the Protection of the Ozone Layer which expressed the political commitment to go further than the requirements of the Montreal Protocol.

5. The Second Meeting of the Parties to the Montreal Protocol was held in London from 27 to 29 June 1990. At this Meeting, the Parties adopted the adjustments and the Amendment to the Montreal Protocol. The adjustment strengthens the control measures (Article 2), requiring the Parties to phase out the production and the consumption of the five CFCs and the three halons listed in Annex A of the Protocol by the year 2000. The adjustments which are binding to all Parties to the Protocol, entered into force on 7 March 1991.

6. The London Amendment to the Montreal Protocol includes the control of ten other CFCs, carbon tetrachloride and methyl chloroform. The production and consumption of these substances are required to be phased out by the year 2000 except for methyl chloroform which should be phased out by the year 2005. The Amendment also includes a strengthened provision on the transfer of technology and a financial mechanism that will facilitate the necessary transfer of technology and enable developing countries to comply with the Protocol. The London Amendment entered into force on 10 August 1992.

7. The Fourth Meeting of the Parties to the Montreal Protocol was held in Copenhagen in November 1992, at which the Parties adopted

further adjustments and Amendment to the Montreal Protocol. The adjustments require the phase-out of five CFCs in Annex A of the Protocol by 1996 and the three halons by the year 1994. All the Parties to the Montreal Protocol must comply with these further strengthened control measures.

8. The Copenhagen Amendment requires additional substances, HBFCs to be phased out by the year 1996 and HCFCs by the year 2030. The consumption of methyl bromide should be frozen at 1991 levels by the year 1995 and meanwhile further studies will be carried out on the impact of methyl bromide on the ozone layer and the economic implications of the phase out. Also in 1995, the Parties will conduct a review of the implementation of the provisions on the technology transfer and the financial mechanism and decide how these control measures should apply for the developing countries. The Copenhagen Amendment entered into force on 14 June 1994.

9. As of 30 June 1994, 136 States and the EEC were Parties to the Vienna Convention and 135 States and the EEC were Parties to the Montreal Protocol. The London Amendment has been ratified by 87 States and the EEC while the Copenhagen Amendment has been ratified by 27 States.

(b) The United Nations Framework Convention on Climate Change

10. During the 1980s, scientific evidence about the possibility of global climate change led to growing concern which in turn led to urgent calls in international conferences for a global treaty to address the problem. UNEP and WMO responded by establishing the Intergovernmental Panel on Climate Change (IPCC) to provide an assessment of the science, impacts and possible response strategies related to climate change. On the basis of the assessment, the United Nations General Assembly in 1990 established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC) which was mandated to draft a framework convention and any related legal instruments that it considered necessary. Negotiators from over 150 states met during five sessions in 1991 and 1992 until on 9 May 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was adopted.

11. The ultimate objective of the Convention and any other legal instruments that the Parties to the Convention may adopt, is to achieve stabilisation of the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Convention states that such levels should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to enable economic development to proceed in a sustainable manner.

12. The UNFCCC was opened for signature at the United Nations Conference on Environment and Development (UNCED) in June 1992 in Rio de Janeiro. Over 150 States signed the Convention at UNCED. The Convention entered into force on 21 March 1994. Currently 78 States are Parties to the Convention. The First Conference of the Parties will be held in March 1995 in Berlin.

Comparison of Some Major Features Under the Three Legal Instruments

(a) Framework Convention with Protocols

13. Both the Vienna Convention and the UNFCCC are framework conventions. A framework convention is a general treaty that resolves in principle to tackle the problem with a view to follow the effort with a more difficult task of agreeing on protocols or other legal instruments that establish specific controls to achieve the objective of the convention.

14. The main thrust of the Vienna Convention is an agreement on cooperation with regard to scientific research and observation to improve the understanding of the atmospheric processes, as well as on formulation of legislative and administrative measures to reduce and eliminate the use of substances that might deplete the ozone layer. It also requires cooperation on exchange of information on technical, socio-economic, commercial and legal aspects of the protection of the ozone layer. The discussions on the Convention had moved forward in parallel with discussions on a protocol on specific controls on the production and consumption of the ozone depleting substances (ODS). By March 1985, agreement was reached on all details of the convention and it was adopted. This was, in itself, a remarkable achievement, being the first international agreement that acknowledged the possible harmful effects to humans, other living creatures and the environment, and the nations agreed in principle to tackle a global environmental problem before its effects were felt, or its cause scientifically proven. However it took two more years of difficult negotiations before the Montreal Protocol was adopted in 1987.

15. Similarly the UNFCCC requires that Parties promote and cooperate in various research, systematic observations and development of data sets with the intention to further the understanding regarding various aspects of climate change and related response strategies. The UNFCCC also contains

commitments which are stronger than those under the Vienna Convention. The UNFCCC defines the common but differentiated responsibilities with consideration for specific national and regional development priorities, objectives and circumstances. These commitments are discussed under sub-section (d) below on "Taking into Account Equity and Social Considerations". It should be noted that for the protection of the ozone layer, provisions for emission controls and financial considerations also exist but under the Montreal Protocol in much stronger provisions with concrete targets and mechanisms to achieve the targets.

(b) The Dynamism of the Legal Instruments

16. One of the important features of the Montreal Protocol which made it a historic and unique international legal instrument is the requirement for the control measures to be revised at least every four years (starting in 1990), based on the review and assessment of latest available informatioh on scientific, environmental, technical and economic aspects of the depletion of the ozone layer. In 1988, four international assessment panels consisting of hundreds of experts from all over the world, were established under the Montreal Protocol to review the latest information on the four aspects.

17. This provision enables the control measures to be adjusted and amended in accordance with the most up-to-date, balanced and independent assessment of the situation with regard to the actual depletion of the ozone layer and its effects as well as the feasibility of the phase out of the controlled substances in terms of technology and economics. The Panels have carried out two assessments—one completed in 1989 and the other in 1991. The second assessment was carried out two years after the first in light of the increasing severity of the ozone layer depletion and fast technological developments on substitutes and alternatives for the controlled substances. The findings of the Panels have formed an important basis for the drawing up and the subsequent adoption of the adjustments and the Amendments to the Protocol.

18. The UNFCCC also contains provisions to ensure dynamism. The Convention requires periodic review of the adequacy of the commitments in light of the best available scientific information and assessment on climate change and its impacts as well as relevant technical, social and economic information. Based on the review, the Parties must take appropriate action which may include amendments of the commitments contained in the Convention. The first review of the commitments for the developed countries will take place at the first meeting of the Conference of the Parties, the second one not later than the end of 1998 and subsequent ones at regular intervals thereafter until the objective of the Convention is met. The implementation of the Convention by the Parties and the effects of the measures taken pursuant to the Convention in achieving the objective of the Convention must also be assessed. Provisions are also included for adopting protocols to the Convention. This enables specific controls of greenhouse gases and other measures to be included as protocols.

(c) The Scientific Assessment

19. From the start of the international actions to protect the ozone layer, scientific assessment played a vital role. When UNEP began to respond to the call for action in 1977, the Coordinating Committee on the Ozone Layer (CCOL) was established to carry out studies and assessments on the depletion of the ozone layer. By 1980, the CCOL produced assessments of potential depletion of the ozone layer with good confidence, showing that there was, indeed, a serious threat to human health and the well-being of the planet due to ozone depletion. Consequently, the *Ad Hoc* Working Group of Legal and Technical Experts for the Elaboration of a Global Framework Convention for the Protection of the Ozone Layer was established. Assessments by the CCOL continued during the negotiations on the Vienna Convention and the Montreal Protocol.

20. Under the Montreal Protocol a provision was included to continue the assessment periodically and to revise the control measures on the basis of the latest information obtained through the assessment. In accordance with this provision, four international panels of scientists and technical experts were established to review the latest information on the scientific, environmental, technological and economic aspects related to the ozone layer depletion and the substances that deplete the ozone layer. The results of the assessment were vital for the strengthening of the Montreal Protocol through adjustments and amendments.

21. Similarly to lay the basis for climate change negotiations, an Intergovernmental Panel on Climate Change (IPCC) was established jointly by UNEP and WMO in order to carry out assessments on the science and potential impacts of climate change as well as on the options of response strategies to adapt to and mitigate climate change and associated economic considerations. The first assessment was completed in 1990 and discussed extensively during the Second World Climate Conference. This was updated in 1992 and the second assessment is due in 1995. Before the completion of the second assessment the IPCC will prepare

a Special Report to the first meeting of the Conference of the Parties. The IPCC's opinion combines the best predictions of those issues tempered with the full range of uncertainties and unknowns and it represents the viewpoint of hundreds, even thousands of the world's best scientists and technical experts. The work of the IPCC has been and will continue to be the foundation for the negotiation on climate change.

22. Using scientific information as the basis for decision-making is the most effective way of ensuring adoption of sound plan of action. When there are scientific uncertainties precautionary approach should be advocated. Action should be taken before serious, adverse effects and irreversible damages occur from environmental changes. The Vienna Convention and the Montreal Protocol are good examples of actions taken to avoid the possible future damage to the environment before irreversible damage actually occurred. The UNFCCC also includes a provision for precautionary principle. The Parties are required to take cost effective precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects. The UNFCCC further states that lack of full scientific certainty should not be used as a reason for postponing such measures.

23. Unlike the Montreal Protocol, the UNFCCC does not contain specific provisions that require scientific assessment for the purposes of reviewing the commitments. Instead, the UNFCCC establishes under it two Subsidiary Bodies: one for Scientific and Technological Advice to provide timely information and advice to the Conference of the Parties on scientific and technological matters related to the Convention; and another for implementation to assist the Conference of the Parties in the assessment and review of the effective implementation of the Convention. Unlike the Assessment Panels under the Montreal Protocol which comprise scientists and experts to provide an independent scientific assessment, the Subsidiary Bodies under the Convention comprise government representatives competent in the relevant fields. These Bodies must function under the guidance of the Conference of the Parties.

(d) Taking into Account Equity and Social Considerations

24. When addressing and tackling problems of global nature, cooperation and participation of all nations are an obvious imperative. The results of any actions taken to reduce or resolve the global problem can only be effective globally when all nations make the effort to implement those actions.

25. In order to ensure full cooperation, the provisions in international treaties must be fair to every nation. This necessarily requires equity and socio-economic considerations to be taken into account. The question of equity under international environment treaties focuses mainly on:

(a) defining the objectives that would ensure intergenerational equity so that the future generation will not have to bear the adverse consequences of the past and present generations;
(b) providing resources from countries where they are available to the countries where they are needed to ensure inter-country equity so that nations do not have to sacrifice unfairly the national development priorities;
(c) distributing the responsibilities in such a way as to ensure that the countries that have and are contributing most to the problem should bear a heavier burden.

26. In the case of Montreal Protocol, it was assessed by the Science Assessment Panel that for the ozone layer to return to its pre-industrial state, all countries in the world must join the effort to halt the emission of the ozone depleting substances into the atmosphere in accordance with the phase out schedule specified under the control measures in the Montreal Protocol. Hence, the intention under the Protocol is to involve all the countries in its activities to phase out the consumption of the ozone depleting substances in order to halt the depletion of the ozone layer and bring it back to its natural state.

27. The Montreal Protocol includes provisions that take into account the special situation of countries, in particular, the developing countries. The main provisions include the following:

(a) The developing-country Parties that have ODS consumption levels below a threshold level defined under the Protocol are eligible to delay compliance with the control measures for 10 years for purposes of satisfying the basic domestic needs. They can also continue to import (from Parties only) and consume the ODS upto that threshold level during the 10-year delay period and should they be unable to obtain adequate supply of the controlled substances that it needs, this Party can submit a notification to the Secretariat, which will then be considered by the Parties for appropriate action.
(b) The financial mechanism which includes a Multilateral Fund and other bilateral and regional cooperation, provides new and additional financial resources to cover the agreed incremental costs incurred by developing countries (that have ODS

consumption below the threshold levels) in complying with the Montreal Protocol. Through the financial mechanism technical and technological cooperation is also provided to enable and facilitate the compliance with the Protocol by those developing countries. The financial mechanism under the Montreal Protocol is the first one of its kind ever established. It reflects the recognition that the developed countries were mainly responsible for the damage to the ozone layer and the need for global partnership to halt and reverse the damage. Resources are now provided by the developed countries to achieve the necessary cooperation and global action.

(c) The Parties are required to take every practicable step to ensure that best available, environmentally safe technologies related to ODS substitutes are transferred to the developing countries under fair and most favourable conditions.

28. The UNFCCC also takes into consideration equity and socio-economic issues. The UNFCCC defines the common but differentiated responsibilities with consideration for specific national and regional development priorities, objectives and circumstances. The main commitments that apply to all Parties include:

(a) Periodic preparation and submission of national inventories of anthropogenic emissions by sources and removal by sinks of greenhouse gases;

(b) Formulation, implementation and publishing of national and, where appropriate, regional programmes containing measures to mitigate climate change and measures to facilitate adequate adaptations to climate change; and

(c) Promotion and cooperation to diffuse, including transfer, of technologies, practices and processes that control, reduce or prevent the anthropogenic emissions of greenhouse gases.

29. In addition, the developed countries as the first step, are also required to aim to reduce their emissions of greenhouse gases either individually or jointly, to the 1990 levels with recognition that in order to meet the objective of the Convention it is desirable for the anthropogenic emissions of greenhouse gases to return to earlier levels by the end of this decade. The developed countries must also provide financial resources to meet the agreed full incremental costs incurred by developing countries in complying with some specific commitments in the Convention. The UNFCCC also calls for certain degree of flexibility in the implementation of the commitments by countries with their economies in transition in consideration of the difficulties that they are likely to face whereas the developed countries are expected to take the lead. The implementation of the UNFCCC by developing countries are stated to be dependent on the effectiveness of the implementation by the developed countries of their commitments related to financial mechanism and technology transfer.

30. The UNFCCC includes a provision for Joint Implementation for the purpose of enabling any Party to reduce its emissions of greenhouse gases jointly with another Party. For example, a Party may count as its greenhouse gas reduction, a project that it undertakes together with another Party in increasing the sinks of greenhouse gases or increasing the energy efficiency. However, criteria and guidelines for Joint Implementation are still to be developed and agreed upon. Joint Implementation is supposed to contribute to ensuring intercountry equity in the following ways:

(a) Some countries rely considerably on non-greenhouse-gas-emitting energy production or have already achieved considerable energy efficiency. These countries would have to incur considerable costs in trying to reduce its emissions of greenhouse gases. Such countries can still meet the required greenhouse gas emission targets in a cost effective way through implementation of greenhouse gas reducing projects that are cheaper and at the same time also beneficial to another country.

(b) The Joint Implementation has the potential of facilitating the channelling of private funds from developed to developing countries and transfer of technology through the project implementation.

31. Joint Implementation, however, raises even greater equity issues than it solves and needs to be further examined to ensure that it does not become an excuse for countries not to take the difficult decisions of reducing the greenhouse gas emission reduction in their own countries.

32. Apart from the provision on Joint Implementation, other provisions that take into consideration inter-country equity issues also have the danger of becoming an excuse for inaction. For example, under the UNFCCC there is a provision which states that full consideration must be given to Parties, particularly the

developing countries, that are vulnerable to adverse effects of the implementation of the commitments. Notably these countries are the ones whose economy is heavily dependent on the greenhouse gas emitting products and technologies. Unless there is a will by those countries to do their best to reduce their greenhouse gas emissions, the provision may be used as an excuse not to act.

(e) Incentives to Become a Party

33. The provisions that take into account the equity and socio-economic aspects act also as incentives, especially for the developing countries to become Parties to the legal instruments. In addition to those provisions other provisions could be built into the international treaties so that implementation of those provisions would result in socio-economic benefits and advantages. Such benefits and advantages will act as strong incentives for participation in the international treaties by all countries.

34. The advantages of joining the Montreal Protocol include the following:

(a) *Access to Latest Technology:* The Parties are in a better position to acquire the technologies for producing and using substitutes as well as for reducing the use and emission of the controlled substances through the provisions on transfer of technology and the financial mechanism. The non-Parties are likely to have to operate for a longer period with technologies that are rapidly becoming obsolete. Continuing the use of obsolete technologies and building new facilities that use obsolete technologies would be a disadvantage economically since it will result in loss of export market for the non-Party industries.

(b) *Preserving/Gaining Access to the World Markets:* When the Parties obtain the new technologies for producing or using substitutes, they will be able to compete better in the world market for selling/exporting the substitutes and related products. Experience of some international companies have shown that the alternative technologies are often cost effective and lead to improvement in the quality of end-products. The industries in the Party countries that use new technologies will gain competitive advantage in export markets.

(c) *Trade Restrictions with Non-Parties in Controlled Substances or Products Containing those Substances:* The trade provisions in the Montreal Protocol require Parties to ban, from specific dates, trade of ODS and the products containing controlled substances. However, any country that is actually complying with the control measures will be treated as a Party for the purposes of the trade provisions, and any Party that is not complying will be treated as a non-Party. Whether or not a country is in compliance with the control measures will have to be determined by the Meeting of the Parties. Such restrictions encourage countries not to stay outside the Protocol. This incentive gained a momentum of its own when more and more countries including the producers and exporters of the ODS and related products became Parties.

35. Under the Montreal Protocol many developing countries are phasing out the controlled substances faster than required, without taking the advantage of the 10-year allowed delay in compliance with the control measures. This has occurred due to the existence of the incentives under the Protocol and greater advantages gained from the faster phase out.

36. Under the Framework Convention on Climate Change the commitment to reduce the emissions of greenhouse gases has its associated socio-economic benefits. The increase of energy efficient production methods and products would incur cost savings and bring competitive business advantages to industries. Reforestation and afforestation would also result in protection and enhancement of forest resources and of biodiversity. Such measures would contribute to sustainable development. Access to funds by the developing countries from the financial mechanism under the UNFCCC to carry out such greenhouse gas reducing activities is provided only for the Parties.

Some Lessons From the Vienna Convention and the Montreal Protocol for Climate Change

37. The story of the Montreal Protocol is both extraordinary and unprecedented and the successful experience of the Vienna Convention and the Montreal Protocol proved to be useful for the climate change negotiations. However, the climate change issue is a very complex one, much more complex than the issue of ozone layer protection and elimination of ODS. In order to control the emissions of greenhouse gases effectively to mitigate climate change virtually all sectors of community must take action. The further work required under the Framework Convention on Climate Change will require tremendous cooperation, understanding, goodwill

and persistence of all nations. This poses a great challenge for the international community.

38. Under the Framework Convention on Climate Change, it is clear and well recognised that further negotiations are required to review the commitments in the Convention and to decide on further action for more stringent measures of action for all Parties. Some of the useful lessons from the Vienna Convention and the Montreal Protocol that may be utilised could be summarised as below:

(a) *An Independent Review of the Latest Scientific Information:* The importance of scientific information and advice for development of measures to take concrete action is clear. The IPCC has been providing the required scientific assessment and information for the climate change negotiations in an effective way. The Convention does not provide a role for the IPCC beyond the first meeting of the Conference of the Parties but only refers to the IPCC under the interim arrangements. However, the Parties could decide to formalise its role under the Convention. The work of the international Assessment Panels under the Montreal Protocol has been the foundation of success in developing rational and effective measures to strengthen the Montreal Protocol.

(b) *Financial Mechanism and Technology Transfer:* The financial mechanism under the UNFCCC is to be decided by the Conference of the Parties. The interim mechanism for the UNFCCC is the Global Environmental Facility (GEF). The Conference of the Parties will be deciding on whether to name GEF as the "permanent" financial mechanism or to establish a new mechanism. One prominent difference between the Multilateral Fund for the Montreal Protocol and GEF is the policy decision making mechanism. For the Multilateral Fund, matters including policies related to the functioning of the Multilateral Fund is decided by the Executive Committee which has an equal representation of the developed and developing countries, with balance in the geographical representation, to ensure fairness in the decision making. This has contributed to the success of the operation of the Multilateral fund, but whether or not a similar mechanism would be suitable for tackling the climate change issue is yet to be seen.

(c) *Built-in Incentives:* As explained in sub-section (e) above, the Montreal Protocol has provisions that result in socio-economic benefits for the Parties. These provisions have acted as strong incentives for joining and implementing the Protocol. Devising and adopting provisions that lead to incentives should be an important aspect in the further work under the UNFCCC.

(d) *Non-Compliance:* Under the Montreal Protocol the Non-compliance Procedure established an Implementation Committee to consider and examine all submissions, information and observations on a case of non-compliance with a view to securing amicable solutions on the basis of respect for the provisions of the Protocol. The Committee submits any recommendations to the Meetings of the Parties which decide on steps to bring about full compliance including measures to assist the Parties' compliance. The Parties also adopted an indicative list of measures that may be taken by the Parties in respect of non-compliance. The measures are: (a) assistance including technical and financial assistance, technology and information transfer and training; (b) issuing caution; and (c) suspension of specific rights and privileges under the Protocol. Since the only real specific action to be taken by individual countries under the UNFCCC is the submission of national inventories of the sources and sinks of greenhouse gases, there is not yet a requirement to devise a procedure for dealing with non-compliance. However, as and when definite targets of greenhouse gas emission reductions become a legal obligation, a mechanism would be necessary to examine the compliance to those obligations.

(e) *Information Dissemination, Training and Networks:* Under the financial mechanism for the Montreal Protocol, the Implementing Agencies (UNDP, UNEP, UNIDO and the World Bank) are carrying out activities in their relevant fields of competence, to assist the Parties in implementing various projects and activities for the phase out of ODS. The activities of UNEP as an Implementing Agency under the Multilateral Fund in the financial mechanism is being undertaken by UNEP's Industry and Environment Programme Activity Centre (UNEP IE/PAC) in its OzonAction Programme.

One of the responsibilities of the OzonAction Programme is to provide a clearing house for the required exchange of information that facilitates the implementation of the Montreal Protocol by the Parties which is being carried out through preparation and dissemination of information materials and technical reports, Information Database by on-line systems and diskette versions as well as through organisation of training and awareness workshops and seminars. In addition, a successful activity is the operation of Networks in different regions of the world. The Networks are for the "ODS officers" who are government officials who are in charge of designing and implementing strategies for ODS phase out. Through the Networks various aspects of the Montreal Protocol and its implementation are discussed and needs of the developing countries are identified. Evaluation of the first Network established in SE Asia has shown that the countries participating in the Network has found it to be very helpful and useful for their efforts to comply with the Protocol.

Such information exchange and training activities are also being carried out in support of the implementation of the UNFCCC. UNEP and the Interim Secretariat for the UNFCCC have established a joint project on "Climate Change Information Exchange Programme" or CC:INFO (previously known as Climex). This project aims to match the resources needed with resources available through collection and dissemination of information on country and organisation activities. The preliminary report on the information that has been collected through the project is soon to be made available widely. The Interim Secretariat and UNITAR are also carrying out a project on "Training Programme to Promote the Implementation of the Convention" or CC:Train.

UNEP is now planning and developing projects to establish and operate Climatic Impacts and Response Strategies Networks (CIRSNet) for various regions and sub-regions. Drawing on the Network experience under the Montreal Protocol, the CIRSNet will be for climate change national government focal points of developing countries to facilitate the development of response strategies and identification and implementation of research and other activities required for the development of the response strategies. This should contribute to capacity building in developing countries to deal with climate change problems. In light of the complexity of the climate issue, the plan is to establish regional CIRSNet of national government focal points and national networks to involve the various sectors of community affected by climate change in order to enable the development of appropriate national response strategies and programmes.

The Networks will be operated within a framework of a Climate Convention Cooperation Programme being developed by the Interim Secretariat and UNDP in cooperation with UNEP and UNITAR. This is a Programme to provide an overall strategic framework to ensure synergy and coordination for the various activities that assist the Parties in implementing the Convention. The framework will be developed directly out of the Convention and the decisions of the Intergovernmental Negotiating Committee (INC) on Climate Change and of subsequent decisions by the Conference of the Parties.

Who Should Abate Carbon Emissions? An International Viewpoint

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Abstract—We review the optimal pattern of carbon emission abatements across countries in a simple multi-country world. We model explicitly (with the model in Chichilnisky, 1993b) the fact that the atmosphere is a public good. Within this framework we establish conditions for it to be necessary for optimality that the marginal cost of abatement be the same in all countries. These conditions are quite restrictive, and amount to either ignoring distributional issues between countries or operating within a framework within which lump-sum transfers can be made between countries. These results have implications for the use of tradeable emission permits, which as normally advocated will lead to the equalisation of marginal abatement costs across countries. The observation that the atmosphere is a public good implies that we may need to look at a Lindahl equilibrium rather than a Walrasian equilibrium in tradeable permits.

Who Should Abate?

The 1992 Rio Convention acknowledged the need for international cooperation in responding to the threat of climate change posed by the rapidly increasing concentration of CO_2 in the atmosphere. There are, however, substantial differences of opinion both about the main issues and about the framework for resolving them. Industrial countries typically focus on the potential problems posed by the growth of population in developing countries, and on the environmental pressure from carbon emissions that this could create over the next half century. Abatement efforts, they feel, should be initiated in the developing countries. On the other hand, developing countries view the carbon emission problem as one which originates historically and currently in the industrial countries, and one which requires their immediate action. Indeed the large majority of all carbon emissions, about 73%, originate currently and historically in the OECD countries and in the ex-Soviet Union; the developing countries have almost 4/5 of the world's population yet contribute at most 30% of all carbon emissions.[1]

CO_2 emissions are a by-product of animal life, and of economic activity which involves burning fossil fuels. The rapid increase in the concentration of CO_2 in the atmosphere which has occurred since the second world war has become a matter of great concern, as it could lead to major and irreversible climate changes. This concentration affects us all equally, because CO_2 mixes uniformly throughout the planet's atmosphere.

From the economic viewpoint, therefore, the abatement of carbon emissions increases our consumption of a *public good,* a "better" atmosphere. However, this differs from the classic public good in that it is not produced in a centralised fashion. Its production is decentralised: Each consumer of the atmosphere is also a producer. Each country uses the atmosphere as a "sink" for the carbon emissions which are a by-product of its economic activities. We have therefore a public good which is independently *produced* as well as *consumed* by all, a case which is closer to that of an economy with externalities, e.g. Baumol and Oates (1977 and 1988); and Heal (1990). The classic questions of optimality in the provision of the public good now become questions about the optimal abatement levels of the different countries. Who shall abate, and by how much? And how are the optimality conditions for abatement related to the countries' levels of income, their marginal costs of abatement, and the efficiency of their abatement technologies?

We find some answers to these questions in a simple model of the world economy (introduced in Chichilnisky, 1993b) consisting of a finite number of countries.[2] Each country has a utility

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[1]There is more detail in Chichilnisky (1992, 1993, a, b), and Chichilnisky and Heal (1993)

[2]It is, in fact, consistent with that of Baumol and Oates (1977 and 1988) Chapter 4.

function which depends on the consumption of a public good and of a private good, such as income. The production of private good emits carbon dioxide as a by-product, and in each country the private good can be transformed into the public good through an abatement technology.

We show that Pareto efficiency dictates that the marginal cost of abatement in each country must be inversely related to that country's marginal valuation for the private good (Proposition 1). In particular, it is not generally true that Pareto optimality requires that marginal abatement costs be equated across countries: This is true only if marginal utilities of income are equated across countries, either by assumption or by lump sum transfers across countries. If richer countries have a lower marginal valuation of the private good, then at a Pareto efficient allocation, they should have a larger marginal cost of abatement than the lower income countries. With diminishing returns to abatement, this implies that they should push abatement further.

There is a presumption in the literature that efficiency requires equalisation of marginal abatement costs: this presumption underlies proposals for the use of uniform carbon taxes and tradeable carbon emission permits (Weyant, 1993; Coppel, 1993). However, in view of the public good nature of the atmosphere and the fact that carbon emissions are produced in a decentralised fashion, efficiency will not in general require the equalisation of marginal costs of abatement across countries without lump sum transfers.

In a two-country example we show that, at an efficient allocation, the quantity of income allocated by a country to abatement is inversely proportional to the level of income—or consumption of that country, with the constant of proportionality increasing with the efficiency of the country's abatement technology (Proposition 2).

The equalisation of marginal costs would be necessary for Pareto efficiency if the goods under consideration were private goods. But in our case we are dealing with a *public* good, i.e. one which, by definition, is consumed by all in the same quantity: the atmospheric CO_2 concentration. This public good is "produced" by the CO_2 emissions (or by the abatement of these emissions) of a finite number of large agents, namely the countries. In this sense, it differs from the classical treatments of Lindahl and Bowen, which were extended subsequently by Samuelson, see Atkinson and Stiglitz, p. 489, footnote 3, (1980). In those cases the public good is produced by a single agent, as is the case for a law and order or defense.

Pareto Efficient Abatement Strategies

Consider a world economy with N countries, $N \geq 2$, indexed by $n = 1,\ldots, N$. Each country has a utility function u_n which depends on its consumption of private goods c_n, and on the quality of the world's atmosphere, a, which is a public good. Formally, $u_n(c_n, a)$ measures welfare, where $u_n: R^2 \to R$ is a continuous, concave function and $\partial u_n/\partial c_n > 0$, $\partial u_n/\partial a > 0$. The quality of the atmosphere, a, is measured by for example the reciprocal or the negative of its concentration of CO_2. The concentration of CO_2 is "produced" by emissions of carbon, which are positively associated with the levels of consumption of private goods, c_n,: i.e.

$$a = \sum_{N=1}^{N} a_n \text{ where } a_n = \phi_n(c_n),$$

$$\text{for each country } n = 1,\ldots,N, \phi_n' < 0 \forall_n. \qquad (1)$$

a is a measure of atmospheric quality overall, and a_n is an index of the abatement carried out by country n. The "production functions" ϕ_n are continuous, and show the level of abatement or quality of the atmosphere decreasing with the output of consumption. An allocation of consumption and abatement across all countries is a vector

$$(c_1, a_1,\ldots, c_N, a_N) \in R^{2N}.$$

An allocation is called *feasible* if it satisfies the constraint (1). A feasible allocation $(c_1^*, a_1^*,\ldots, c_N^*, a_N^*)$ is *Pareto efficient* if there is no other feasible solution at which every country's utility is at least as high, and one's utility is strictly higher, than at $(c_1^*, a_1^*,\ldots, c_N^*, a_N^*)$.

A Pareto efficient allocation must maximise a weighted sum of utility functions

$$W(c_1,\ldots,c_n,a) = \sum_{n=1}^{N} \lambda_n u_n(c_n,a)$$

with $\sum_n \lambda_n = 1$ subject to feasibility constraints. Varying the λ_ns, one traces out all possible Pareto efficient allocations. The λ_ns are of course exogenously given welfare weights, and a standard set of weights is $\lambda_n = 1/N$ for all n. We are assuming in this formulation that utilities are comparable across countries. This means that we cannot change the units of measurement of utility in any country without making similar changes in other countries. Each country n faces a constraint in terms of allocating total endowments into either consumption c_n or atmospheric quality, a_n, represented by the function ϕ_n. Then a Pareto efficient allocation is described by a solution to the problem:

$$\text{Max } W(c_1,\ldots,c_n,a) = \sum_{n=1}^{N} \lambda_n u_n(c_n,a), \qquad (2)$$

subject to $a_n = \phi_n(c_n), n = 1 \ldots N$ and $a = \sum_{n=1}^{N} a_n$. (3)

Note that, by definition, the marginal cost of abatement is the inverse of the marginal productivity of the function ϕ_n:

$$MC_n(a_n) = -1/\phi_n'(c_n) \quad (4)$$

A Pareto efficient solution solves problem (2).

Proposition 1. *At a Pareto efficient allocation $(c_1^*, a_1^*, \ldots, c_N^*, a_N^*)$, the marginal cost of abatement in each country, $MC_n(a_n^*)$, is inversely proportional to the marginal valuation of the private good c_n, $\lambda_n \partial u_n / \partial c_n$. In particular, the marginal costs will be equal across countries if and only if the marginal valuations of the private good are equal, i.e., $\lambda_n \partial u_n / \partial c_n$ is independent of n.*

Proof. The solution to the maximisation problem (2) must satisfy the first order conditions:

$$\lambda_j \partial u_j / \partial c_j = -(\sum_{n=1}^{N} \lambda_n \partial u_n / \partial a)\phi_j'$$

for each country $j = 1 \ldots N$. Since at a Pareto efficient allocation the expression $(\Sigma_{n=1}^{N} \lambda_n \partial u_n / \partial a)$ is the same constant for all countries, denoted K, and since, as noted in (4)

$$MC_n(a_n^*) = -1/\phi_n'(c_n)$$

we have that a Pareto efficient allocation is characterised by:

$$MC_j(a_j^*) = \frac{K}{\lambda_j \partial u_j / \partial c_j}$$

and the proposition follows. ◊

Proposition 1 shows that the product of the marginal valuation of private consumption and the marginal cost of abatement in terms of consumption, is equal across countries. Writing this product $\lambda_j, \partial u_j / \partial c_j . \partial c_j / \partial a$, we see that it can be interpreted as the marginal cost of abatement in country j measured in utility terms, i.e. in terms of its contribution to the social maximand $\Sigma_n \lambda_n u_n(c_n, a)$. An immediate implication is that in countries which place a high marginal valuation on consumption of the private good, typically low income countries, the marginal cost of abatement at an efficient allocation will be lower than in other countries. If we assume an increasing marginal cost of abatement (diminishing returns to abatement), then this of course implies lower levels of abatements in poor countries than in rich countries.

Under what conditions can we recover the "conventional wisdom" that marginal abatement costs should be equalised across countries? We need to equate the terms $\lambda_n \partial u_n / \partial c_n$ across countries. This could be done *by assumption*: We can just decide as a value judgment that is an input to the planning problem that consumption will be valued equally on the margin in all countries. Given the enormous discrepancies between the income levels in OECD countries and countries such as India and China, and the need for all of them to be involved in an abatement programme, such a value judgment seems most unattractive. It is, however, implicitly done in simulation models which seek to maximise world GNP or similar measures.

There is an alternative possibility. Modify the original problem to allow unrestricted transfers of private goods between countries:

Max $W(c_1, c_2 . c_n, \ldots, a) = \sum_n \lambda_n u_n(c_n, a)$

subject to $a_n = \phi_n(y_n)$ and $a = \sum a_n$ and $\sum y_n = \sum c_n$ (5)

This is the same as before except that we now distinguish between the consumption of the private good by country n, denoted c_n, and the production of the private good by country n, denoted y_n. These need not be equal. In addition we now require the sum of the consumptions across countries to equal the sum of the productions $-\Sigma y_n = \Sigma c_n$, instead of having these equal on a country by country basis. By this modification we are allowing the transfer of goods between countries, i.e., we are allowing lump sum transfers. Note that this is not a model of international trade, which would require the imposition of balance of trade constraints. Clearly the first order conditions now are just

$$\lambda_n \frac{\partial u_n}{\partial c_n} = \upsilon \forall n \quad (6)$$

$$\phi_n' \sum \lambda_i \frac{\partial u_i}{\partial a} = -\upsilon \forall n \quad (7)$$

Set $K = \sum \frac{\partial u_i}{\partial a}$. Hence from (6) and (7) we get

$$\lambda_n \frac{\partial u_n}{\partial c_n} = -\phi_n' K \quad (8)$$

as before. However, we now have an extra condition (6)—namely $\lambda_n \frac{\partial u_n}{\partial c_n} = \upsilon \quad \forall n$.

Substituting this into (8) gives

$$\upsilon = -\phi_n' K$$

which of course implies that physical marginal cost is the same across all countries, as υ and K are common to all countries. So if we solve an optimisation problem that allows unrestricted transfers between countries, and we make the transfers that are needed to solve this problem, it will then be efficient to equate marginal abatement costs.

Consider now the case of two countries, each with a Cobb-Douglas utility function,

$$u_n(c_n, a) = c_n^{\alpha}(a)^{1-\alpha} = c_n^{\alpha}(a_1 + a_2)^{1-\alpha},$$

where the abatement production function ϕ_n is

$$a_n = \phi_n(c_n) = k_n(Y_n - c_n)^{1/2}, k_n > 0, \text{ for } n = 1, 2,$$

for example, $k_1 = k$ and $k_2 = 1$. This allows us to accommodate potentially different efficiencies of abatement across countries. For simplicity, the two countries are assumed to have the same utility function. In this case:

Proposition 2. *At a Pareto efficient allocation, the fraction of income which each country allocates to carbon emission abatement must be proportional to that country's income level, and the constant of proportionality increases with the efficiency of the country's abatement technology.*

Proof. Our problem (2) can now be written as:

$$\text{Max}_{c_1 c_2} W(c_1, c_2) =$$

$$\text{Max } \{c_1^{\alpha}[k(Y_1 - c_1)^{1/2} + (Y_2 - c_2)^{1/2}]^{1-\alpha} + c_2^{\alpha}[k(Y_1 - c_1)^{1/2} + (Y_2 - c_2)^{1/2}]^{1-\alpha}\}$$

Let

$$A = [k(Y_1 - c_1)^{1/2} + (Y_2 - c_2)^{1/2}].$$

The first order conditions for a maximum are then:

$$\alpha c_1^{\alpha-1} A^{1-\alpha} - 1/2(Y_1 - c_1)^{-1/2}$$
$$k\{c_1^{\alpha} A^{-\alpha}(1-\alpha) + c_2^{\alpha}(1-\alpha)A^{-\alpha}\} = 0$$

and

$$\alpha c_2^{\alpha-1} A^{1-\alpha} - 1/2(Y_2 - c_2)^{-1/2}$$
$$\{c_1^{\alpha} A^{-\alpha}(1-\alpha) + c_2^{\alpha}(1-\alpha)A^{-\alpha}\} = 0,$$

which simplify to:

$$\left(\frac{c_1}{c_2}\right)^{\alpha-1} = k\left(\frac{Y_1 - c_1}{Y_2 - c_2}\right)^{-1/2}.$$

Since $\alpha < 1$ this implies that for Pareto efficiency, the income allocated to abatement by each country ($a_n = Y_n - c_n, n = 1, 2$) must be proportional to the income level, or the level of consumption, of the country (c_n). Furthermore the larger the abatement productivity of a country ($k = k_1$), the larger is its abatement allocation as a proportion of income. ◊

Abatement Costs, Taxes and Emission Permits

While the atmosphere is a classic public good in terms of consumption, it is produced in a decentralised way, and the first order conditions for efficient allocation and provision of this "good" are different from the classical ones and closer to those characteristic of a general externality, as modelled in Heal (1990).

Once the optimal consumption/abatement levels in each country are found, then *quotas* on emissions could be assigned to each country on the basis of these levels, and *permits* could be issued and freely traded as financial instruments across countries on the basis of these quotas. A system of permits for carbon emissions has of course been contemplated for some time, but as far as we know, the country-by-country quotas for these permits have not been connected to the optimality conditions for the allocation of public goods produced in a decentralised way. It would be desirable to ascertain what form of market organisation for the permit market would be required in order to reach efficiency. For example, would it involve uniform pricing as in a competitive market, or rather personalised prices as in a Lindahl equilibrium? This should be a subject for further research.

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What is Sustainable Development?*

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Abstract—The paper proposes two axioms that capture the idea of sustainable development and derives the welfare criterion that they imply. The axioms require that neither the present nor the future should play a dictatorial role.

Theorem 1 shows there exist *sustainable preferences*, which satisfy these axioms. They exhibit sensitivity to the present and to the long-run future, and specify tradeoffs between them. It examines other welfare criteria which are generally utilised: discounted utility, lim inf, long-run averages, overtaking and catching-up criteria, Ramsey's criterion, Rawlsian rules, and the criterion of satisfaction of basic needs, and finds that none satisfies the axioms for sustainability.

Theorem 2 gives a characterisation of all continuous *sustainable preferences*. Theorem 3 shows that in general sustainable growth paths cannot be approximated by paths which approximate discounted optima. Proposition 1 shows that paths which maximise the present value under a standard price system may fail to reach optimal sustainable welfare levels, and example 4 that the two criteria can give rise to different value systems.

1. Introduction

Economics is at a crossroads created by two major trends. One is advances in information technology, which are changing the way we work, live and think. The other is the environmental agenda, which leads us to reconsider the foundations of economics, the central questions of resource allocation. Economics traditionally considers resources as passive, so to say "there for the taking". But many resources are alive, like forests or biodiversity, and even those that are not alive have their own rationale and dynamics, such as the planet's atmosphere or its water bodies. The interaction of resources with human organisations such as markets requires attention now because for the first time in recorded history, human activity has reached levels at which it can alter the global environment, such as the planet's climate and its biological mix.

Understanding the interaction between resources and human organisations is not an easy task. While economic motives are the driving force behind the destruction of the world's biodiversity and the changes to the planet's atmosphere, economics does not measure and therefore cannot perceive properly the consequences of economic actions, which are biological or geophysical. Each science sees only one side of the equation.

The need for reformulating the economics of resource allocation is plain to outsiders who demand it, but takes an abstract and rarified form for the economist. It appears for example as a call for "sustainable development" strategies within international organisations,[1] a term which has not been defined until now and which many still consider undefinable. Nonetheless, the useful survival of economics as a discipline lies in its ability to adjust its principles and its analysis and to offer needed insights and policies. We must ask what is sustainable development, and we must find an answer on which economics can be built reliably and usefully.

In the broadest sense, sustainable development means development which gives an equal opportunity to future generations. Current patterns of development conjure up

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[1]E.g. the World Bank, the United Nations and the OECD.

images of "slash and burn" industrialisation. The industrial countries with the highest levels of income consume most of the earth's resources, and generate most of the carbon emissions from their burning of fossil fuels.[2] Global carbon emissions generated since the second world war are generally believed to have the ability to alter seriously the earth's climate, although there is as yet no scientific agreement on the precise magnitude of the effects. Biologists see the loss of biodiversity during the last 50 years as one of the four or five largest incidents of destruction of life in the planet.

The evidence of the last 50 years shows that carbon emissions and biodiversity loss are inversely related to population growth. Carbon emissions are positively related to the level of a country's income, because they are closely connected with energy use. Industrial countries which have 1/5 of the world's population, the highest income levels and the lowest population growth, use most of the world's produced energy and correspondingly emitting about 70% of the world's carbon, while developing countries, which contain about 4/5 of the world's population and the highest rates of population growth, account for only about 30% of the world's emissions.[3] These observations support the current view that the patterns of growth in the industrial countries may not be sustainable and should probably not be imitated by developing countries. They could be incompatible with the sustainable use of one of the most valuable resources: the planet's atmosphere. Several years ago in the *Bariloche Model*[4] we pointed out that the patterns of development followed by industrial societies were probably not sustainable, and should not be imitated by developing countries. We introduced and formalised the concept of development based on the satisfaction of basic needs (Chichilnisky, 1977b), and carried out an empirical analysis of world development based on this criterion, which we showed to be more consistent with the planet's resources and with its ecological dynamics.[5]

Further impetus to the same theme was given in 1987 by the Brundtland Commission which updated the term "sustainability" and anchored it also to the concept of needs: Development should "satisfy the needs of the present without compromising the needs of the future".[6]The 1992 Earth Summit in Rio de Janeiro also saw sustainable development as one of the most urgent subjects for international policy: Sustainable development is the official charge of one of the three Conventions which were made responsible for advancing environmental policy in the international arena. The other two Conventions are on Climate Change and Biodiversity, but it has been said the sustainable development comprises the three. The topic is therefore of widespread interest, and is compelling to many. But *what is sustainable development?*

Solow (1992) pointed out that recent discussion of sustainability has been mainly an occasion for the expression of emotions and attitudes, with very little analysis of sustainable paths for a modern industrial economy. He suggests that sustainable development should mean that we are not to consume humanity's capital, in a general sense. But the replacement of one form of capital with another is, in his view, acceptable. As a thought experiment, consider the replacement of all trees on the planet by equally valuable capital stock. Are we to deem this as sustainable development?A large number of people would disagree strongly with such a view, although many economists would not. There is an ambiguity here in how value is defined, and in this lies the crux of the matter. How do we define economic value? What shall we measure and how?

Value is usually defined in terms of utility. This is almost a tautology in the case of an individual, but leads to notorious difficulties when attempting to compare the utilities of different people and of different generations. The quotes given above suggest that the crux of the matter is how to describe value so that it does not underestimate the future's interests, so that the future is given an equal treatment. Also implicit in the statement that sustainable development must satisfy the needs of the present without compromising the future's is the idea of fair treatment for both the present and the long-run future. The challenge is therefore to develop economic theory which formalises this aim, the equal treatment for the present and for the future, with the level of clarity and substance achieved by neoclassical growth theory. The formalisation should suggest a programme of empirical research with clear implications for public policy.

To follow this plan of action, we need to start from a clear notion of how to rank alternatives and how to evaluate tradeoffs. From such rankings practical criteria for optimality are

[2]Chichilnisky (1991).

[3]Coppel (1973). Chichilnisky (1993a).

[4]Herrera et al. (1976) and Chichilnisky (1977a).

[5]We introduced the concept of economic development based on the satisfaction of basic needs (Chichilnisky, 1977b), and analysed its empirical implications for patterns of economic development on five continents (Herrera et al., 1976).

[6]Brundtland (1987). Chapter 2, para 1.

derived, which allow us to evaluate alternatives and tradeoffs, the essential elements of an economist's task.

This paper proposes simple axioms which capture the concept of sustainability. They require intergenerational equity in the sense that neither the "present" nor the "future" should be favoured over the other. We neither accept the romantic view which relishes the future without regards for the present, nor the consumerist view which ranks the present above all. But is there anything left?

The answer is, perhaps surprisingly, yes. What is left is a characterisation of a family of *sustainable preferences* which has points in common with Hicks' notion of income as a "sustainable" level of consumption (Hicks, 1946). These preferences are sensitive to the welfare of all generations, and offer an equal opportunity to the present and to the future. Tradeoffs between present and future consumption are allowed. The examples and the characterisation of the family of sustainable preferences appears in Theorems 1 and 2, which also show the sustainable preferences are different from all other criteria used so far in the analysis of optimal growth and of markets.

But how different is this criterion in practice from other standard measures? Does it lead to different optimal paths from those which emerge from using discounted utility? Can we always approach sustainable optima by paths which in the foreseeable future resemble those of discounted optima, albeit with small discount rates.

An answer to these questions is in Theorem 3 and Corollary 1. These show that sustainable optima can be quite different from discounted optima, no matter how small is the discount factor. The difference is most striking in decision problems with irreversibilities, which impose constraints today leading to substantial differences in the long run, as in Example 1. But the general issue is that captured by Hicks' idea of income, and by Solow's concern for not consuming humanity's capital: the long run has a substantial weight.

It remains to show how practical is our criterion for ranking development paths and for evaluating projects. This is the subject of companion papers, Beltratti et al. (1993) and Heal (1993), which study "green golden rules" and sustainable optimal growth paths. They compute optimal solutions and derive shadow prices which can be used to decentralise optimal solutions, although possibly not by the maximisation of the present value of profits under standard price systems.[7]

The axioms and the characterisations we propose have a compelling minimal logic, but they are by no means unique. They are meant as an aid to formalising our thinking on sustainability and as a way of providing a level of analytical clarity which could improve our understanding. Analytical underpinnings are as necessary for the practical evaluation of sustainable policies as they are for our thinking of the available options.

2. The State of the Art

The theory of economic growth was developed about 50 years ago, and reflects the patterns of development which were followed throughout this period. Exponential growth of population and resource use are viewed as steady states. Most studies of optimal growth and most project evaluations rank alternatives using a discounted utility criterion. However, discounting future utility is generally inconsistent with sustainable development. It can produce outcomes which seem patently unjust to later generations. Indeed under any positive discount rate, the long-run future is deemed irrelevant.

For example, at a standard 5% discount rate, the present value of the earth's aggregate output discounted 200 years from now, is a few hundred thousand dollars. A simple computation shows that if one tried to decide how much it is worth investing in preventing the destruction of the earth 200 years from now on the basis of measuring the value of foregone output, the answer would be no more than one is willing to invest in an apartment.

This appears to contradict the observation that people and their governments seem seriously concerned with the long-run future and willing to invest substantial sums of money to control the disposal of nuclear waste or to prevent global climate change. Both involve potentially disastrous risks and very long time horizons. For example, a recent OECD study considers a global carbon tax yielding a revenue of US$150 billion annually.[8] Practitioners have argued that discounted utility is inappropriate for evaluating the costs of global warming, given the very long time horizons involved, and have suggested that the use of a zero discount rate be considered.[9]

However, several criteria for the project evaluation and optimal growth which have been proposed to take into consideration the long-run future, share a drawback: their insensitivity to present generations.[10] They involve

[7]The expression present value under standard price systems means a value which is defined by a sequence of dated prices, a sequence which defines a (finite) value for all bound sequences of commodities. See definition in section 8.

[8]Coppel (1993) and Chichilnisky (1993a).

[9]Broome (1992) and Cline (1992).

[10]Beltratti et al. (1993).

undiscounted methods such as long-run averages and lim-infimum rules. In fact, these rules ignore the welfare of any finite number of generations, no matter how large this number may be.

It is also possible to select development paths using a Rawlsian criterion, Rawls (1971), or alternatively the criterion of satisfaction of basic needs, Chichilnisky (1977b). In addition, welfare criteria other than discounted utility have been proposed for evaluating optimal growth paths by Ramsey (1928), von Weizacker (1967), Gale (1967) and Koopmans (1963), see also Hammond (1993), Heal (1985) and McFadden (1967).

It seems fair to say that no criterion has achieved the analytical clarity of the discounted sum of utilities: For this criterion there are simple conditions for the existence of optimal paths; a characterisation of optimal paths, and prices which can decentralise a social optimum.[11] In an analytical sense, discounted utility compares favourably with Rawlsian rules and basic needs, which take into consideration solely the welfare of the neediest, but are rather insensitive, giving the same welfare weight to any two utility streams which coincide in the utility of the neediest, even though one may provide strictly higher welfare to an infinitely large number of generations. The discounted utility criterion is, by contrast, sensitive to increases in utility by any one generation. In fact, the sustainable welfare criteria introduced here also satisfies such sensitivity: If a utility stream is strictly larger than another in at least one generation, then it ranks it higher.

The discounted utility criterion shows also its analytical strength when compared with Ramsey's criterion and von Weizacker's overtaking criterion, because these latter criteria are incomplete orders which fail to rank many reasonable alternatives. The discounted utility criterion, is instead, a complete order. The problem is simple: The overtaking criterion fails to rank any two paths which switch between overtaking and being overtaken by the other, as shown in Fig. 1 below, and leads to a seriously incomplete or indecisive ranking of alternative paths. A similar difficulty emerges with Ramsey's criterion, which ranks paths according to their

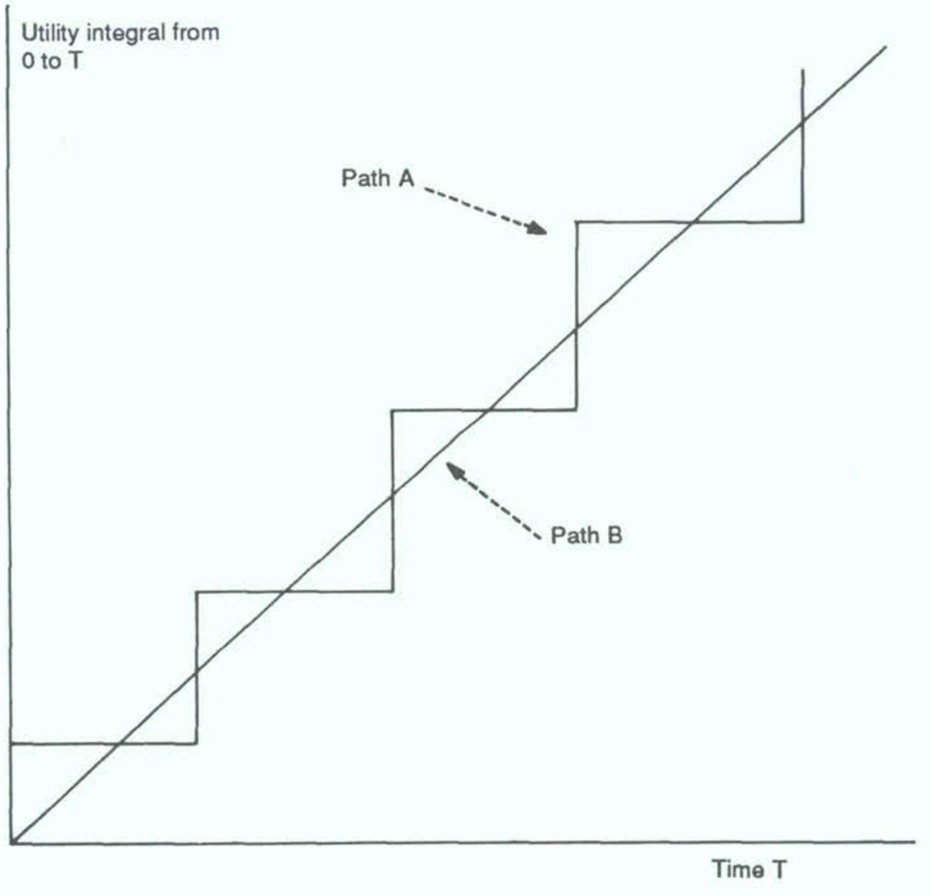

Fig. 1. The overtaking criterion cannot rank paths A and B.

[11]See Arrow and Kurz (1970), Dasgupta and Heal (1979), and Chichilnisky and Kalman (1980).

distance from a blissful level of consumption, a distance which is measured according to the area between the path to be evaluated and the bliss path. Such distances are often ill-defined, because in an infinite world the measure of the area between two bounded paths could be unboundedly large. Therefore we again meet indecisiveness on the part of the ranking. Instead, discounted utility provides a complete ranking of all feasible paths. Our sustainable welfare criterion is also a complete ranking. The usefulness of an indecisive criterion is limited, since in many important cases the criterion yields no choice, and, as has already been argued, the task for economists is to develop a criterion for sustainable development with a level of analytical clarity and completeness similar to that which has been achieved by the parts of neoclassical growth theory which rest on discounted utility.

These concerns motivate the axioms of sustainability, the results of an existence and characterisation of the welfare criteria which satisfy these axioms, which I call *sustainable preferences*, and the study of the connection between sustainable preferences and other welfare criteria in the literature.

3. Social Choice and Sustainable Development

I propose two axioms which reflect a concern about sustainable welfare for infinitely many generations. These axioms are non-dictatorship properties, and as such have a direct connection with social choice theory.[12]

A welfare criterion used to evaluate sustainable development must be a complete order over utility paths which does not assign a dictatorial role either to the present or to the future, and which increases with increases in the welfare of any generation. Axiom 1 requires that the present should not dictate the outcome in disregard for the future: It requires sensitivity to the welfare of generations in the distant future. This, it turns out, eliminates the discounted utilitarian approach. Axiom 2 requires that the welfare criterion should not be dictated by the long-run future, and thus requires sensitivity to the present. This latter axiom eliminates lim inf and long run averages which only consider the very long run. In this sense, the axioms require a form of symmetry or "equal treatment" of the present and of the future, one which is reminiscent of the anonymity condition in social choice.[13]

Theorem 1 shows that Axioms 1 and 2 eliminate all known criteria for evaluating infinite utility streams used so far in the literature. It also establishes that there exists a well-defined class of welfare criteria which do satisfy the two axioms: Preferences which satisfy these two axioms have not been used before, and I call them *sustainable preferences*.

Theorem 2 identifies completely all the continuous welfare criteria which satisfy the axioms:[14] This is useful because continuity has the role of ensuring the existence of sufficient statistics. When the welfare criterion has the same rate of substitution between the utilities of any two generations whatever their levels of utility, sustainable preferences are shown to have a simple and general characterisation.

Because it is important that the axioms should be practical in nature, and usable for solving sustainable optimal growth problems and evaluating sustainable projects, companion papers[15] study optimal growth models with renewable resources,[16] in which the welfare criterion are sustainable preferences. These I call *sustainable growth models*. The results in Beltratti et al. (1993) and Heal (1993) exhibit the extent to which the use of these axioms leads to a well-defined optimum growth theory with the analytical clarity and substance of neoclassical growth theory. In Beltratti et al. (1993) we characterise a "green golden rule" which is the natural extension of the "golden rule" of neoclassical growth theory, and analyse sustainable optimal growth paths. The aim is to offer a *sustainable optimal growth* analysis at the level of applicability of neoclassical growth theory.

Sustainable preferences can of course be used in a general equilibrium context as well. When the market economy is infinitely lived, a hypothesis which is often made in order to eliminate the potential inconsistencies arising from unknown terminal dates, it may be appropriate and indeed desirable that the traders and the producers should have sustainable preferences. Indeed, current German national accounting practices include a concept of sustainability of the enterprise in the determination of a firm's income. It has been suggested that Universities' budgetary decisions, which typically involve a requirement of keeping the long-run value of the institution intact, have sustainable characteristics as well.[17]

[12]See Arrow (1953), Chichilnisky (1994). In this case we are concerned with fairness across generations, see also Solow (1974), Lauwers (1993), Lauwers and van Liederkierke (in press).

[13]Chichilnisky (1982, 1993b).

[14]*Continuity has been used profitably in social choice theory for the last ten years, see* Chichilnisky (1982, 1993b).

[15]Beltratti et al. (1993) and Heal (1993).

[16]Chichilnisky (1993b).

[17]I owe this comment to Donald Kennedy, Chairman of the Global Environment Programme at the Institute for International Studies of Stanford University, and ex-president of Stanford University.

4. Sustainability and Value

In addition to introducing axioms for sustainability and characterising the welfare functions that satisfy them, I show the paths that maximise the present value of profits may be quite different from a sustainable optimum. In particular, it may not always be possible to decentralise the solutions by means of "market prices" as in neoclassical growth theory.[18] Theorem 3 and Corollary 1 show that even if an optimal sustainable solution exists and is unique, in general it will not be approximated by paths which are optimal under discounted criteria, no matter how small the discount rate.

Environmental assets may therefore have a well defined and sustainable value according to a sustainable preference, but an arbitrarily small market or profit maximising value, as in Example 4. The concept of present value of profits may differ substantially from the value implicit in our axioms for sustainability. In general, however, there will be some overlap between the two, and some tradeoffs will be possible.

5. Axioms for Sustainability

Consider an infinitely lived world, an assumption that obviates the need to make decisions contingent on an unknown terminal date. Each generation is represented by an integer g, $g = 1 \ldots \infty$. Generations could overlap or not; indeed one can in principle consider a world in which some agents are infinitely long lived. In this latter case, one is concerned about the manner in which infinitely long lived agents may wish to inject considerations of sustainability into the evaluation of development paths for their own futures.

In order to compare the axioms and results to those of growth theory we shall adopt a formulation which is as close as possible to that of the neoclassical model. Each generation g has a utility function u_g for consumption of n goods, some of which could be environmental goods such as water, or soil, so that consumption vectors are in R^n, and $u_g: R^n \to R^+$. The availability of goods in the economy could be constrained in a number of ways, for example by a differential equation which represents the growth of their stock of a renewable resource,[19] and/or the accumulation or depreciation of capital. Ignore for the moment population growth, although this issue can be incorporated at the cost of simplicity, but with little change in the results.[20] The space of all feasible consumption paths is indicated F.

$$F = \{x : x = \{x_g\}_{g=1,2,\ldots}, x_g \in R^n\}. \tag{1}$$

In common with the neoclassical growth literature, utility across generations is assumed to be comparable; in order to eliminate some of the most obvious problems of comparability we normalise the utility functions u_g so that they all share a common bound, which we assume without loss of generality to be 1:

$$\sup_g (u_g(x_g))_{x_g \in R^n} \leq 1. \tag{2}$$

The space of **feasible utility streams** Ω is therefore

$$\Omega = \{\alpha : \alpha = \{\alpha_g\}_{g=1,2,\ldots}, \alpha_g = u_g(x_g)\}_{g=1,2,\ldots}$$
$$\text{and } x = \{x_g\}_{g=1,2,\ldots} \subset F\} \tag{3}$$

Because I normalised utilities, each utility stream is a sequence of positive real numbers, all of which are bounded by the number 1. The space of all utility streams is therefore contained in the space of all infinite bounded sequences of real numbers, denoted ℓ_∞.[21] Our welfare criterion W should rank elements of Ω, for all possible $\Omega \subset \ell_\infty$.

5.1. Sensitivity and Completeness

The welfare criterion W must be represented by an increasing real valued function on the space of all bounded utility streams[22] $W: \ell_\infty \to R^+$. The word increasing means here that if a utility stream α is obtained from another β by increasing the welfare of some generation, then W must rank α strictly higher than β.[23] This eliminates the Rawlsian criterion and the basic needs criterion, both of which, as we saw, are rather insensitive to the welfare of all generations but those with the lowest welfare. Completeness and sensitivity eliminate the Ramsey theory criterion as well as the overtaking criterion.

[18] It can be shown that this occurs because the "cone condition" which is necessary and sufficient for supporting optimal growth programmes with non-zero price sequences defined by Chichilnisky and Kalman (1980), Chichilnisky (1993c) and used for example by Mas-Collel, is typically not satisfied in sustainable growth models.

[19] See (Chichilnisky, 1993d) and (Beltratti et al., 1993).

[20] Populations growth and utilitarian analysis are well known to make an explosive mix, which is, however, outside the scope of this paper.

[21] Formally: $\Omega \subset \ell_\infty$ where $\ell_\infty = \{y : y = \{y_g\}_{g=1,\ldots} : y_g \in R^+, \sup_g |y_g| < \infty\}$. Here |.| denotes the absolute value of $y \in R$, which is used to endow ℓ_∞ with a standard Banach space structure, defined by the norm ||.|| in ℓ_∞

$$\|y\| = \sup_{g=1,2,\ldots} |y_g|. \tag{4}$$

The space of sequences ℓ_∞ was first used in economics by G. Debreu (1954).

[22] The representability of the order of W by a real valued function can be obtained from more primitive assumptions, such as e.g., transitivity, completeness and continuity conditions on W.

[23] Formally: If $\alpha > \beta$ then $W(\alpha) > W(\beta)$.

5.2. The Present

How to represent the present? Intuitively, when regarding utility streams across generations, the present is the part of those streams that pertains to finitely many generations. The present will therefore be represented here by all the parts of feasible utility streams which have no future: For any given utility stream α, its "present" is represented by all finite utility streams which are obtained by cutting α off after any number of generations. Formally:

Definition 1 *For any utility stream $\alpha \in \ell_\infty$, and any integer K, let α^K be the "K-cutoff" of the sequence α, the sequence whose coordinates up to and including the K-th are equal to those of α, and zero after the K-th.*[24]

Definition 2 *The present consists of all feasible utility streams which have no future, i.e., it consists of the cutoffs of all utility streams.*

5.3. No Dictatorial Role for the Present

Definition 3 *We shall say that a welfare function $W: \ell_\infty \to R$ gives a dictatorial role to the present, or that W is a dictatorship of the present, if W is insensitive to the utility levels of all but a finite number of generations, i.e., W is only sensitive to the "cutoffs" of utility streams, and it disregards the utility levels of all generations from some generation on.*

Formally, W is a dictatorship of the present if for any two utility streams[25] *α, β*

$$W(\alpha) > W(\beta) \Leftrightarrow$$
$$\exists N = N(\alpha, \beta) \text{ s. t. if } K > N,\ W(\alpha^K + \gamma_K) > W(\beta^K + \sigma_K)$$
$$\text{for any utility streams } \gamma, \sigma \in \ell_\infty.$$

The following axiom eliminates dictatorships of the present:

- **Axiom 1: No Dictatorship of the Present.**

This axiom can be seen to eliminate all forms of discounted sums of utilities, as shown in Theorem 1.

5.4. The Future

By analogy, for any given utility stream α, its "future" is represented by all infinite utility streams which are obtained as the "tail" resulting from cutting α off for any finite number of generations. Formally:

Definition 4 *The "K-th tail" of a stream of $\alpha \in \ell_\infty$, denoted α_K, is the sequence with all coordinates equal to zero up to and including the K-th, and with coordinates equal to the coordinates of α after the K-th.*[26]

For any two $\beta, \gamma \in \ell_\infty$, $\beta^K + \gamma_K$ is of course the sequence defined by summing up or "pasting together" the *K-th* cutoff of β with the *K-th* tail of γ.

5.5. No Dictatorial Role for the Future

Definition 5 *We shall say that a welfare function $W: \ell_\infty \to R$ gives a dictatorial role to the future, or equivalently that W is a dictatorship of the future, if W is insensitive to the utility levels of any finite number of generations, or equivalently it is only sensitive to the utility levels of the "tails" of utility streams.*

Formally: For every two utility streams α, β

$$W(\alpha) > W(\beta) \Leftrightarrow$$
$$\exists N = N(\alpha, \beta) \text{: if } K > N,$$
$$W(\gamma^K, \alpha_K) > W(\sigma^K, \beta_K), \forall \gamma, \sigma \in \ell_\infty.$$

The welfare criterion *W* is therefore only sensitive to the utilities of "tails" of streams, and in this sense the future always dictates the outcome independently of the present. The following axiom eliminates dictatorships of the future:

- **Axiom 2: No Dictatorship of the Future.**

This axiom excludes all welfare functions which are defined solely as a function of the limiting behaviour of the utility streams. For example, it eliminates the lim-inf and the long-run averages.

Definition 6 *A sustainable preference is a complete sensitive preference satisfying axioms 1 and 2.*

6. Previous Welfare Criteria

While the axioms proposed in the previous section appear quite reasonable, and they could be said to have a compelling minimal logic, they suffice to exclude most welfare criteria used in the literature. In this section I shall define some of the more widely used welfare criteria, and also provide examples which will be used in Theorem 1 of the next section.

A function $W: \ell_\infty \to R$ is called a **discounted sum of utilities** if it is of the form:

$$W(\alpha) = \sum_{g=1}^{\infty} \lambda_g \alpha_g, \forall \alpha \in \ell_\infty, \tag{5}$$

[24] In symbols: $\alpha^K = \{\sigma_g\}_{g=1,2,\ldots}$ such that $\sigma_g = \alpha_g$ if $g \le K$ and $\sigma_g = 0$ if $g > K$.

[25] Recall that all utility streams are in ℓ_∞ and they are normalised so that $\sup_{g=1,2\ldots}(\alpha(g)) = \|\alpha\| < 1$ and $\sup_{g=1,2\ldots}(\beta(g)) = \|\beta\| < 1$.

[26] In symbols: $\alpha_K = \{\sigma_g\}_{g=1,2\ldots}$ such that $\sigma_g = 0$ if $g \le K$ and $\sigma_g = \alpha_g$ if $g > K$.

where $\forall_g, \lambda_g \geq 0$ and $\sum_{g=1}^{\infty} \lambda_g < \infty; \lambda$ is called the discount factor. **Ramsey's welfare criterion** (Ramsey, 1928) ranks a utility stream $\alpha = \{\alpha_g\}_{g=1,2...} \in \ell_\infty$ above another $\beta = \{\beta_g\}_{g=1,2...} \in \ell_\infty$ if the utility stream α is "closer" to the bliss path, namely to the sequence $\sigma = \{1, 1, ..., 1, ...\}$, than is the sequence β. Formally:

$$\sum_{g=1}^{\infty}(1-\alpha_g) \leq \sum_{g=1}^{\infty}(1-\beta_g). \tag{6}$$

A Rawlsian rule (Rawls, 1971) ranks two utility streams according to which has a higher infimum value of utility for all generations. This is a natural extension of the criterion proposed initially by Rawls (1971). Formally: A utility stream α is preferred to another β if

$$\inf \{\alpha_g\}_{g=1,2...} > \inf \{\beta_g\}_{g=1,2...} \tag{7}$$

The criterion of **satisfaction of basic needs** (Chichilnisky, 1977b) ranks a utility stream α over another β if the time required to meet basic needs is shorter in α than in β. Formally:

$$T(\alpha) \leq T(\beta), \tag{8}$$

where $T(\alpha) = \min\{t: \alpha_g \geq b \forall_g \geq t\}$, for a given b which represents basic needs. The **overtaking criterion** (von Weizacker, 1967) ranks a utility stream α over another β if α eventually leads to a permanently higher level of aggregate utility than does β. Formally: α is preferred to β if $\exists N$:

$$\forall M > N, \sum_{g=1}^{M} \alpha_g \geq \sum_{g=1}^{M} \beta_g. \tag{9}$$

The **long run average** criterion can be defined in our context as follows: A utility stream α is preferred to another β if in average terms, the long run aggregate utility[27] achieved by α is larger than achieved by β. Formally: $\exists N, K > 0$:

$$\frac{1}{T}\left(\sum_{g=M}^{T+M} \alpha_g\right) \geq \frac{1}{T}\left(\sum_{g=M}^{T+M} \beta_g\right), \forall T > N \text{ and } M > K. \tag{10}$$

7. Existence and Characterisation of Sustainable Preferences

Why is it difficult to rank infinite utility streams? Ideally one wishes to give equal weight to every generation. For example, with finitely many N generations, each generation can be assigned weight $1/N$. But when trying to extend this criterion to infinitely many generations one encounters the problem that, in the limit, every generation is given zero weight.

What is done usually to solve this problem is to attach more weight to the utility of near generations, and less weight to future ones. An example is of course the sum of discounted utilities. Discounted utilities give a bounded welfare level to every utility stream which assigns each generation the same utility. Two numbers can always be compared, so that the criterion so defined is clearly complete. However, the sum of discounted utilities is not even-handed: It disregards the long run future. I show below that as soon as the total welfare assigned to bounded utility streams is well defined, the welfare criterion thus obtained is a dictatorship of the present. Therefore the sum of discounted utilities is unacceptable under my axioms, for any discount factor no matter how small.

Another solution is offered in the theory of repeated games: Here, instead, more weight is given to the future and less to the present. An example is the criterion defined by the long-run average of a utility stream, a criterion used frequently in repeated games. However, this criterion is not even-handed either, this time because it is biased against the present. The decision of ranking one utility stream over another is made on the basis of the long run behaviour of the utility stream, and is quite independent of what any finite number of generations is assigned. We have jumped from an unacceptable extreme to another.

Here matters stood for some time. Asking for the two axioms together, the no-dictatorship of the present and the no-dictatorship of the future, as I do here appears almost as it would lead to an impossibility theorem. But not quite.

It turns out the utilities just described are each unacceptable on their own, but not when taken together. Let's reason again by analogy with the case of finite generations. To any finite number of generations one can assign weights which decline into the future, and then assign some extra weight to the last generation. This procedure, when extended naturally to infinitely many generations, is neither dictatorial for the present nor for the future. It is similar to adding to a sum of discounted utilities, the long run average of a whole utility stream. Neither part of the sum is acceptable on its own, but together they are. In other words: Two partial answers make a complete answer. This is Theorem 1 below. Furthermore, the only way to get things right, under continuity assumptions, is by adding two wrongs. This is Theorem 2 below, which gives a complete characterisation of all continuous sustainable preferences.

Formally, this section establishes that there exist sustainable preferences which satisfy the two axioms: They neither give a dictatorial role to the present nor to the future. This is achieved by taking the sum of two welfare criteria. The first gives a dictatorial role to the present, but it is sensitive to the welfare of each and every generation, for example a sum of discounted utilities. The second part of the sum gives a

[27] This is only one of the possible definitions of long run averages. For other related definitions with similar properties see Dutta (1991).

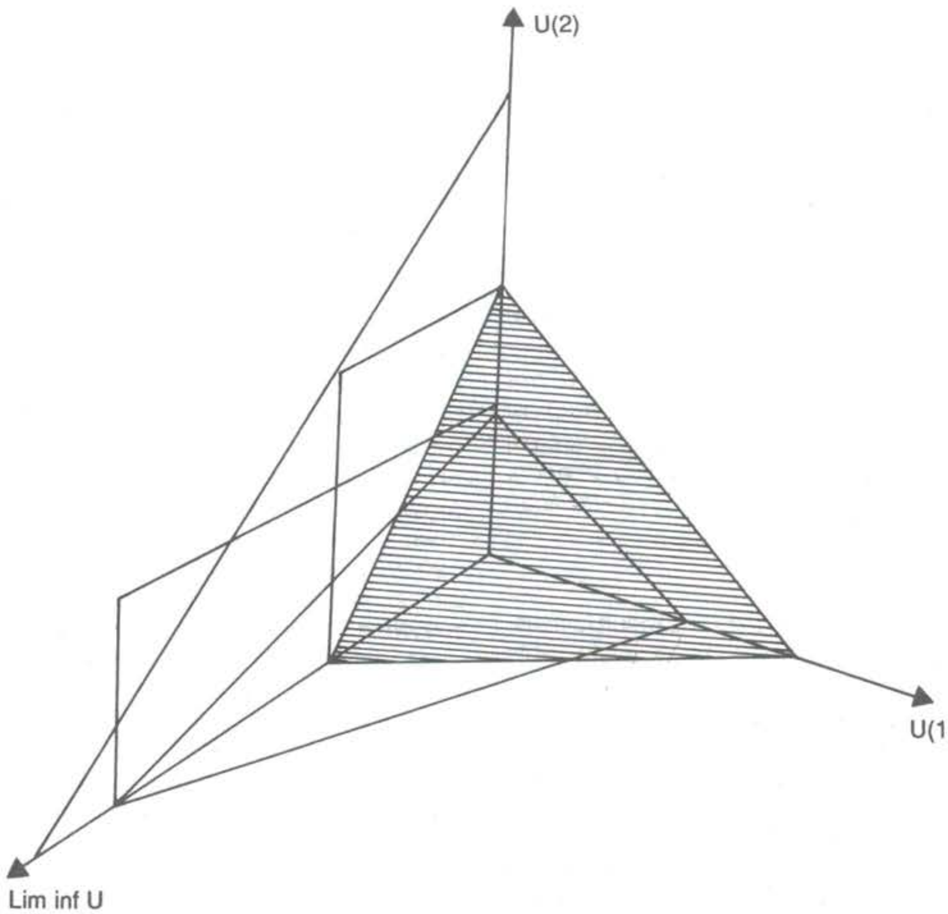

Fig. 2. The 3 axes represent the utilities of finite generations (U (1) and U (2)) and the limiting utility value lim inf U. Two level sets of the ranking are shown. One dominates over finite generations but has a lower lim inf. As the weights on finite generations are fixed, the ranking in these dimensions can be represented by the intersection of the level set restricted to the U (1) – U (2) plane with the vertical axis. The overall ranking is then shown as the sum of this ranking (the countably additive measure) with the ranking in the lim inf dimension (the purely finitely additive measure).

dictatorial role to the future, for example, the long run average of the sequence of utilities. The sum of a dictatorship of the present plus a dictatorship of the future is neither. This is because the first part of the sum is sensitive to the present, and the second is sensitive to the future. Furthermore such a sum admits tradeoffs between the welfare of the present and that of the future. Theorem 1 below shows such preferences do exist; they are represented diagrammatically in Fig. 2, which shows the tradeoffs between the present and the future's utilities. The three axes represent the utility levels of 1, 2 and , figuratively,- ∞. The two triangular planes represent two indifference surfaces. One gives more utility to generations 1 and 2, and under a dictatorship of the present these choices would prevail; however, the second surface gives more utility to the long run, so that under certain conditions the second surface is chosen over the first. Theorem 1 makes this reasoning rigorous.

The second part of Theorem 1 shows that all known criteria of optimality used now fail to satisfy the axioms postulated here: Some, such as the sum of discounted utilities, are dictatorship of the present. Others, such as the long run averages, are dictatorship of the future. Yet others are incomplete, such as overtaking and the Ramsey's criterion, and others are insensitive, such as the Rawlsian criteria and basic needs. Therefore the sustainable preferences defined here perform a role that no previously used criteria did.

What is perhaps more surprising is that the sustainable welfare criteria constructed here, namely the sum of a dictatorship of the present and one of the future, exhaust all of the continuous utilities which satisfy my two axioms. This means that any continuous sustainable preference must be of the form just indicated. This is Theorem 2, proved in the Appendix. The mathematics needed to make all this work is not trivial, but the intuition is clear.

7.1. The Existence of Sustainable Preferences

Theorem 1 *There exists a sustainable preference $W: \ell_\infty \to R$, i.e., a preference which is sensitive and does not assign a dictatorial role to either the present or the future:*

$$W(\alpha) = \sum_{g=1}^{\infty} \lambda_g \alpha_g + \phi(\alpha), \qquad (11)$$

where $\forall_g, \lambda_g > 0, \sum_{g=1}^{\infty} \lambda_g < \infty$, and $\phi(\alpha)$ = *long run average* (α).[28]

The following welfare criteria are not sustainable preferences: (a) the sum of discounted utilities, for any discount factor, (b) Ramsey's criterion, (c) the overtaking criterion, (d) lim inf, (e) long run averages, (f) Rawlsian rules, and (g) basic needs.

Proof. In the Appendix.

An intuitive explanation of this result follows. The preference defined in (11) is sustainable because it is complete, its first term is sensitive to the present, in fact it increases with increases in the welfare of every generation, and its second term is sensitive to the long run future.

(a) The sum of discounted utilities is a dictatorship of the present because for every $\varepsilon > 0$, there exist a generation N so that the sum of discounted utilities of all other generations beyond N is lower than ε for all utility streams since all utilities are bounded by the number 1. Now, given any two utility streams α, β if $W(\alpha) > W(\beta)$ then $W(\alpha) > W(\beta) - \varepsilon$ for some $\varepsilon > 0$; therefore there exists a generation N beyond which the utilities achieved by any generation beyond N do not count in criterion W. This is very true for any discount factor.

(b) The Appendix establishes that the Ramsey's criterion is incomplete; this derives from the fact that the distance to Ramsey's bliss path is ill-defined for many paths.

(c) The Appendix establishes that the overtaking criterion is incomplete: See also Fig. 1.

(d) and (e) lim inf and long run averages are dictatorships of the future.

Both (f) and (g), Rawlsian and basic needs criteria, are insensitive because they rank equally any two paths which have the same infimum even if one assigns much higher utility to many other generations.

Figure 2 represents two indifference surfaces for a sustainable preference as defined in (11).

7.2. A Complete Classification of Sustainable Preferences

The following result characterises sustainable preferences. Additional conditions on the welfare criterion W are now introduced: W is *continuous* when it is defined by a continuous function $W: \ell_\infty \to R$.[29] Continuity has played a useful role in social choice theory in the last ten years, in effect replacing the axiom of independence of irrelevant alternatives and allowing a complete characterisation of domains in which social choice exists, Chichilnisky (1982, 1993b) and Chichilnisky and Heal (1993). A similar role is found here for continuity: The following Theorem gives a full characterisation to all sustainable criteria which are continuous.

W is called *independent* when the rate of substitution between two generations' utilities is independent of their levels of utility;[30] the characterisation of a sustainable criterion W in the following Theorem is simplest when W is continuous and independent.

The following Theorem decomposes a sustainable criterion into the sum of two functions. The first is a discounted utility with variable discount factors and the second is a generalisation of long run averages. Called a *purely finitely additive* measure, this second function ϕ assigns all welfare weight to the very long run. In particular ϕ assigns the value zero to any sequence which has finitely many non zero terms.[31]

Theorem 2 *Let $W: \ell_\infty \to R^+$ be a continuous independent sustainable preference. Then W is of the form $\forall \alpha \in \ell_\infty$:*

$$W(\alpha) = \sum_{g=1}^{\infty} \lambda_g \alpha_g + \phi(\alpha), \qquad (12)$$

where $\forall_g \lambda_g > 0, \sum_{g=1}^{\infty} \lambda_g < \infty$, and ϕ is a purely finitely additive measure.

More generally: Any continuous sustainable preference W, whether independent or not, is of the form:

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[28]The long run average of α is $\lim_{K,N \to \infty} (\sum_{g=N}^{K+N} \alpha_g)$.

[29]A function W which is continuous with respect to the standard norm of the space of sequences ℓ_∞. The norm is $\|\alpha\| = \sup_{g=1,2\ldots} |\alpha_g|$, and was defined above.

[30]See the Appendix. This simply means that the indifference surfaces of the welfare criterion W are hypersurfaces so that it is possible to represent it by a linear function on utility streams: $W(\alpha + \beta) = W(\alpha) + W(\beta)$. Note that this does not restrict the utilities of the generations, u_g, in any way; in particular the u_g's need not be linear.

[31]A finitely additive measure on the integers Z is a function of μ defined on subsets of the integers, satisfying $\mu(A \cup B) = \mu(A) + \mu(B)$ when $A \cap B = \phi$. μ if called purely finitely additive when it assigns measure zero to any finite subset of integers. See also the Appendix.

$$W(\alpha)=\sum_{g=1}^{\infty}\lambda_g^{\alpha}\alpha_g+\phi^{\alpha}(\alpha)$$

where[32] $\lambda_g^{\alpha}=W(0,\ldots,0,\overset{g\text{-th place}}{1},0,\ldots,0,\ldots)>0$, $\Sigma_{g=1}^{\infty}\lambda_g^{\alpha}<\infty, \phi^{\alpha}=\phi^{\alpha}(\alpha)$ *is a purely finitely additive measure of the integers, and for some* $\alpha\in\ell_{\infty}, \lambda^{\alpha}\neq 0$, *and* $\phi^{\alpha}\neq 0$.

Proof. In the Appendix.

8. Sustainable Optima Can Be Far From Discounted Optima

The previous results showed that sustainable preferences are substantially different from other welfare criteria which have been used in the literature. It remains, however, to study how different they are in practice, for example, whether the optimal solutions of problems which maximise sustainable preferences are substantially different from the optimal solutions to discounted problems.

To answer this question I shall compare problems which are defined over the same constraint set, but each of which maximises different welfare criteria. The purpose is to explore what difference this makes in practice. An optimal problem which maximises a sustainable preference will be called a *sustainable problem*. If the welfare criterion is a discounted sum of utilities as defined in (5), I call this a *discounted problem*. The corresponding solutions are called sustainable optima and discounted optima.[33]

Can one always approximate a sustainable optimum by paths which optimise discounted problems? Or even better: Can one always approximate a sustainable optimum by a sequence of paths which approximates the solutions of a discounted problem? The following result gives a negative answer to these questions. It is not always possible to approximate sustainable optima by paths which approach discounted optima. Sustainable optima and discounted optima can be far apart. Nonetheless, sustainable preferences allow for tradeoffs between the welfare of the present and of the future, and present value of profit maximisation is a good approximation for maximising the welfare of the present.[34]

Theorem 3 *Consider a sustainable problem:*

$$Max_{\{\alpha:\,\alpha\in\Omega\}}\, W(\alpha_g), \tag{13}$$

where $W(\alpha)=\sum_{g=1}^{\infty}\lambda_g\alpha_g+\phi(\alpha)$ *is a sustainable preference and* $\Omega\subset\ell_{\infty}$ *is the set of all feasible utility streams. Let* α^* *be a unique sustainable optimum of (13), and* $W^*=W(\alpha^*)$. *Assume also that there exist a unique discounted optimum* β^*, *for the problem of maximising over the same set* Ω *the discounted utility* $\Sigma_{g=1}^{\infty}\lambda_g\alpha_g$. *Then in general the sustainable optima* α^* *cannot be approximated by a sequence of feasible utility streams* $\{\beta^n\}_{n=1,2\ldots}$ *which approximates the discounted optimum* β^*. *This is true for any sequence of discount factors* $\{\lambda_g\}$.

Proof. In the Appendix.

The intuition for this result is in the following example:

Example 1 *Consider an economy which uses trees as a necessary input to production or consumption; without this input the economy's utility is zero. The dynamics of tree reproduction requires that unless the first N periods the economy refrains from cutting more than a certain number of trees, the species becomes extinct after K + N periods, in which case there is zero utility at every period from then on. The economy's feasible set of utility streams* Ω *is described then as follows: A minimum investment denoted* $\varepsilon > 0$ *is required during each of the first N periods to ensure that the utility levels in all periods from the (N + K)-th on is above zero. Once this threshold is reached, then all utility levels in each period after the (N + K)-th exceed* ε. *Then for every discount factor, there is an N, K for which the sum of discounted utilities is maximised at a path which leads to the eventual elimination of the forest. Instead, for a sustainable preference which gives sufficient weight to the long run the optimum will keep the forest alive and yielding a minimum utility level* ε *forever. Therefore the two optima are apart by at least* ε; *any sequence of paths which approaches the discounted optimum will not approach the sustainable solution.*

9. Sustainability and Value

The following corollary and example show that the notion of value derived from sustainable preferences is rather distinctive. Paths which are optimal under sustainable preferences may not maximise present discounted value according to any standard price system. Therefore, environmental resources with a large

[32] $\lambda_g^{\alpha}: Z\to R$ is "the sequence part of W at α, namely the sequence of numbers defined as: $\lambda_g^{\alpha}=W(e_g)$, where $e_g=(0,\ldots,0,\overset{g\text{-th place}}{1},0,\ldots,0,\ldots)$. This representation of W means, in particular, that the map W is different from its sequence part, i.e., cannot be represented as the inner product with a sequence, and is therefore not countably additive.

[33] Formally: Let F be a convex concave and closed subset of feasible paths in a linear space X. Such as for example $X=\ell_{\infty}$, or $X=R^N$. A vector $\beta\in F$ is called optimal in F if it maximises the value of a function $U: X\to R$. The vector β is called a discounted optimum if $U: \ell_{\infty}\to R$ is a discounted sum of utilities as defined in (5); β is called a sustainable optimum if $U: X\to R$ is a sustainable preference.

[34] This result has also implications for the support and decentralisation of sustainable optima (Corollary 1 and Example 4). It may not be possible to approximate sustainable optima by paths which approximately maximise the present value of profits under any standard sequence of prices. However, level independent sustainable preferences can be used in certain cases to define shadow prices at which the optimal paths maximise value. These are "generalised" prices, but they can be given a precise mathematical formulation and a precise economic interpretation. They measure the value both of the short and of the long run, and can be called "sustainable prices".

value in the long run, may not appear valuable under a standard notion of present value profit maximisation.

The following corollary explores the connection between sustainable optima and the maximisation of present value.[35] A **standard price** p is a sequence of prices, $p = (p_1, \ldots, p_g, \ldots)$ which assigns a well-defined present value to every stream, $p(\gamma) = \sum_{g=1}^{\infty} p_g \gamma_g$, for all $\gamma \in \ell_\infty$.[36] There exist continuous linear functions on ℓ_∞ which cannot be represented in this manner. An example is the long run average of a sequence α: this assigns a present value zero to every sequence with finitely many terms. If the long run average was representable as a sequence, in the limit, it would assign zero value to every sequence, which is obviously untrue.[37] The Corollary below and the following Example 4 construct two specific economic examples.

Corollary 1 *There exists a sustainable problem*[38]

$$Max_{\alpha \in \Omega} (W(\alpha)) \tag{14}$$

with the property that its sustainable optimum does not maximise present value within Ω at any standard price $p = (p_1, p_2, \ldots)$. Therefore, for any standard price system p there are suboptimal paths which have strictly large present value than the sustainable optimum α^*, i.e., for all p, $\exists \beta^* \in \Omega$:

$$\sum_{g=1}^{\infty} p_g \alpha_g^* < \left(Sup_{\beta \in \Omega} \sum_{g=1}^{\infty} p_g . \beta_g \right).$$

This result is true for any discount factor.

Proof. This follows readily from Theorems 2 and 3. Without loss of generality, consider the case where the utility functions u_g are the identity map. In this case, the set of feasible utility streams Ω coincides with the set of feasible consumption streams. Furthermore, since the welfare function W defines an independent sustainable preference, the first term of W defines a sequence of standard prices with the desirable properties, namely $p = \{\lambda_g\}_{g=1,2\ldots}$ well-defines the present value $\sum_g \lambda_g \alpha_g$ for each sequence of ℓ_∞.[39] Theorem 3 showed that in general the value maximising sequence β^* is different from α^*. In particular, this implies that the sustainable optimum α^* does not generally maximise value for the standard price system p. Since the results of Theorem 3 are true for any sequence of "discount factors" $\{\lambda_g\}_{g=1,2\ldots}$ satisfying $\forall_g, \lambda_g > 0$ and $\sum_{g=1}^{\infty} \lambda_g < \infty$, the corollary follows. □

9.1. Example 4: A Sustainable Optimum Which Does Not Maximise Expected Value at Any Standard Price System

The results of Corollary 2 can be strengthened further by means of another example. Consider a feasible path $\beta \in \ell_\infty$ which maximises a continuous concave utility function U within a convex set $F \subset \ell_\infty$, but such that at no standard price system p does β maximise present value.[40] For $c \in [0, \infty)$ let

$u_t(c) = 2^t c$ for $c \leq 1/2^{2t}$,
and $u_t(c) = 1/2^t$ for $c > 1/2^t$.

Now, for any sequence $c \in \ell_\infty^+$ let $U(c) = \sum_{t=1}^{\infty} u_t(c_t)$, which is well defined, continuous, concave, and increasing on ℓ_∞^+. Let $\beta \in \ell_\infty^+$ be defined by

$$\beta_t = 1/2^{2t+1}$$

and let[41]

$$F = U^\beta = \{\gamma \in \ell_\infty : U(\gamma) \geq U(\beta)\};$$

F is a closed convex subset of ℓ_∞. Now assume that $p = \{p_t\}_{t=1,2\ldots}$ is a standard supporting price system for the set $U^\beta, p_t \geq 0$, i.e., $p.\gamma \geq p.\beta \forall_\gamma \in U^\beta$. But the usual marginal rate of substitution arguments,

$$p_t = p_1 2^{t-1}. \tag{15}$$

I shall show that p_1 must be zero, so that the whole sequence $\{p_t\}_{t=1,2\ldots}$ must be zero. Assume to the contrary that $p_1 \neq 0$. Define $z \in \ell_\infty^+$ by

$z_t = 1/p_t$

and $z^n \in \ell_\infty^+$ by

[35] Here I consider a special case where the utilities u_g are linear; the problem can then be formulated readily without introducing any further notation. The general case can be analysed along similar lines, at the cost of more notation. General formulations of the problem of optima and intertemporal profit maximisation can be found in the literature (Debreu, 1954); a simple formulation in infinite dimensional spaces that fits well our purposes is in Chichilnisky and Kalman (1980).

[36] In some cases, the present value coincides with intertemporal utility maximisation, see Chichilnisky and Kalman (1980). Note that if p is a standard price system, represented by the sequence $(p_1, p_2, \ldots)$, then by definition this sequence satisfies $\sum_{g=1}^{\infty} p_g < \infty$.

[37] In fact, all purely finitely additive measures on Z define real valued functions on sequences which cannot be represented by sequences.

[38] $\forall_g\ u_g \neq 0$.

[39] It can be shown that the value $p(\alpha) = \sum_g \lambda_g \alpha_g$ can be interpreted as the intertemporal profit of the "plan" α.

[40] This is from Example 1 in Chichilnisky and Heal (1993) p. 369, which is reproduced here for the reader's convenience. This example deals with the minimisation rather than the optimisation of a function over a set, but the results are of course equivalent. The example constructs a feasible set $F \subset \ell_\infty$ which is non-empty, closed and concave, and a continuous concave function $U: \ell_\infty^+ \to R$ which attains an infimum $U(\beta)$ at β in F, such that the only sequence of prices $p = \{p_n\}_{n=1,2\ldots}$ which can support β in F[45] is identically zero.

[41] We call this set U^β in sympathy with the notation of Chichilnisky and Heal (1993).

$z_t^n = \alpha_t^*$ if $t \leq n$, and 0 otherwise.

Then $\forall n$, $z \geq z^n$ so that

$$p(z) \geq p(z^n), \tag{16}$$

but

$\sum_{t=1}^{\infty} p_t z_t^n = n > p(z)$ for some n sufficiently large, contradicting (16).

The contradiction arises from the assumption that p_1 is not zero. Therefore $p_1 = 0$ and by (15) the entire price sequence $p = \{p_t\}_{t=1,2,\ldots}$ is identically zero. It is therefore not possible to support the concave set U^β with a non-zero standard price system.[42] □

10. Conclusions

I have defined a set of axioms which capture the idea of sustainability, and characterise the sustainable preferences that they imply (Theorems 1 and 2). I also analysed other criteria used in the literature, and found that they do not satisfy my axioms (Theorem 1). Discounted utility fails to satisfy the non-dictatorship of the present, Axiom 2, and in this sense it is not appropriate for the study of sustainable development. This agrees with the viewpoint of many practitioners, who have pointed out the inadequacy of discounted utility for analysing sustainable growth.[43] Rawlsian and basic needs criteria are insensitive, since they only regard the welfare of the generation which is less well-off. The *overtaking* criterion and its relative the *catching up* criterion are incomplete as orders. They fail to compare many reasonable alternatives. This decreases their value as aids for decision making. Ramsey's criterion has a similar drawback: it is defined as the integral of the distance to a "bliss" utility level, but this integral can be ill-defined. Even when paths converge to the bliss point, the criterion may fail to rank these paths if the convergence of the path to the bliss level of utility is slow. The Ramsey criterion is therefore incomplete since no finite value can be attached to those paths with ill defined integrals. Another way of looking at the problem is that in many cases the welfare level could be infinite. In such cases, it is impractical to use this criterion as a foundation for policy, since this would involve calculus with infinite magnitudes.[44]

The sustainable preferences proposed here and characterised in Theorem 2 circumvent all of these problems. From the practical point of view, they give rise to optimal solutions which are different from those obtained by discounted optimisation criteria. Theorem 3 and Corollary 1 establish that a path which is optimal under a sustainable preference may not be approximated by paths which approximate discounted optima.

The notion of value derived from sustainable preferences is distinctive. Paths which are optimal under sustainable preferences may not maximise value according to any standard price system (Example 4). Therefore, environmental resources with a large value in the long run, may not appear valuable under a standard notion of profit maximisation.

This may help to disentangle the apparent contradictions in values which were discussed in the beginning of this paper. We noted that governments and international organisations appear prepared to invest sums of money which exceed by several orders of magnitude the discounted value of the planet's economic product in order to prevent potential global climate change. If we accept our axioms for sustainable preferences, the contradiction is resolved. Discounted profit maximisation and sustainability lead to different value systems. Some tradeoffs are possible, but the two values are not the same.

As Solow has proposed, sustainability should allow intergenerational tradeoffs, but no generation should be favoured over any other. This standard is met by sustainable preferences when applied to the "present" and to "future" generations. The long run does matter and so does the short run. Indeed, independent sustainable preferences can define *shadow prices* for sustainable optima, which can be used for project evaluation and for the characterisation of optimal solutions. Several of the aims of this paper have therefore been reached, and several of the questions that we posed have been answered. But perhaps the results open up at least as many new questions.

It remains to understand the concern for the long run future which is observed in practice, and which appears formalised in the axioms proposed here and their implied preferences. Nobody alive today, not even their heirs, has a stake on the welfare of 50 generations into the future. Yet many humans care about the long run future of the planet, and the results of this paper indicate that axioms which formalise this concern are not altogether unacceptable. One may then ask: Whose welfare do sustainable preferences represent?

Perhaps an answer for this riddle may be found in a wider understanding of humankind as an organism who seeks its overall welfare over time. Such proposals have been advanced

[42] Further examples of phenomena related to the results in Theorem 2 and Corollary 1 can be found in Dutta (1991).

[43] E.g. Dasgupta and Heal (1979), Broome (1992), and Cline (1992).

[44] Hammond (1993) has defined agreeable paths as those which are approximately optimal for any sufficiently long horizon, in the sense that the welfare losses inflicted by considering only finite horizons go to zero as the length of the finite horizon goes to infinity. The criterion is not designed as a complete order but rather as a way of identifying acceptable paths. A similar issue arises with the overtaking criterion, which is ill-defined in many cases.

in the concepts of a "selfish gene", or, more practically, in Eastern religions such as Buddhism which view the unity of humankind as a natural phenomenon. If such unity existed, humankind would make up an unusual organism, one whose parts are widely distributed in space and time and who is lacking a nervous system on which the consciousness of its existence can be based. Perhaps the advances in the information technology described at the beginning of this article, with their global communications and processing reach, are a glimmer of the emergence of a nervous system from which a global consciousness for humankind could emerge.

11. Appendix

11.1. Continuity

In practical terms the continuity of W is the requirement that there should exist a sufficient statistic for inferring the welfare criterion from actual data. This is an expression of the condition that it should be possible to approximate as closely as desired the welfare criterion W by sampling over large enough finite samples of utility streams. Continuity of a sustainable criterion function $W: \ell_\infty \to R$ is not needed in Theorem 1; it is used solely for the characterisation in Theorem 2. Continuity is defined in terms of the standard topology of ℓ_∞: The norm defined by $\|\alpha\| = \sup_{g=1,2...} |\alpha(g)|$.

11.2. Independence

The welfare criterion $W: \ell_\infty \to R$ will be said to give independent tradeoffs between generations, and called **independent**, when the marginal rate of substitution between the utilities of two generations g_1 and g_2 depends only on the identities of the generations, i.e., on the numbers of g_1 and g_2, and not on the utility levels of the two generations. Independence of the welfare criterion is not needed in Theorem 1. It is used solely in the characterisation of Theorem 2, to allow us to obtain a simple representation of all sustainable preferences. Formally: Let ℓ_∞^* be the space of all continuous real valued linear functions on ℓ_∞.

Definition 7 *The welfare criterion $W: \ell_\infty \to R$ is independent if $\forall \alpha, \beta \in \ell_\infty$,*

$$W(\alpha) = W(\beta) \Leftrightarrow$$
$$\exists \lambda \in \ell_\infty^*,\ \lambda = \lambda(W), \text{ such that } \lambda(\alpha) = \lambda(\beta)$$

This property has a simple geometric interpretation, which is perhaps easier to visualise in finite dimensions. For example: Consider an economy with n goods and 2 periods. Let $\alpha = (\alpha_1, \alpha_2), \beta = (\beta_1, \beta_2) \in R^2$ denote two feasible utility streams. Then α and β are equivalent according to the welfare criterion $W: R^2 \to R$, i.e., $W(\alpha) = W(\beta)$, if and only if there exists a number $\mu = \mu(W)$, $\mu > 0$, such that

$$\frac{\alpha_2 - \beta_2}{\alpha_1 - \beta_1} = \mu \qquad (17)$$

The geometric interpretation of (17) is that the indifference surfaces of W are affine linear subspaces of R^2. Level independence implies that the indifference surfaces of the welfare function W are affine hyperplanes in ℓ_∞. In particular, W can be represented by a linear function on utility streams, i.e., $W(\alpha+\beta) = W(\alpha) + W(\beta)$. Examples of welfare criteria which satisfy this axiom are all time-separable discounted utility functions, any linear real valued non-negative function on ℓ_∞, and the welfare criterion in Theorem 2. As already mentioned, this axiom is used to provide a tight representation of sustainable preferences, but is not strictly necessary for the main results.

Definition 8 *A continuous independent sustainable preference is a complete, sensitive preference satisfying Axioms 1 and 2 and which is continuous and independent.*

11.3. Countable and Finitely Additive Measures

Definition 9 *Let (S, Σ) denote the field of all subsets of a set S with the operations of unions and intersections of sets. A real valued, bounded additive set function on (S, Σ) is one which assigns a real value to each element of (S, Σ), and assigns the sum of the values to the union of two disjoint sets.*

Definition 10 *A real valued bounded additive set function is called countably additive if it assigns the countable sum of the values to a countable union of disjoint sets.*

Example 2 *Probability measures on the real numbers, R, or on the integers Z, are typical examples of such countably additive functions. Any sequence of positive real numbers $\{\lambda_g\}_{g=1,2...}$ such that $\Sigma_{g=1}^{\infty} \lambda_g < \infty$ defines a countably additive measure μ on the integers Z, by the rule*

$$\mu(A) = \sum_{g \in A} \lambda_g, \forall A \subset Z.$$

Definition 11 *A real value bounded additive set function φ on (S, Σ) is called purely finitely additive (see Yosida and Hewitt, 1952) if whenever a countably additive function υ satisfies:*

$$\forall A \in (S, \textstyle\sum), \upsilon(A) \le \varphi(A), \text{ then}$$
$$\upsilon(A) = 0 \forall A \in (S, \textstyle\sum).$$

This means that the only countably additive measure which is absolutely continuous with respect to a purely finitely additive measure, is the measure which is identically zero.

Example 3 *Any real valued linear function $V: \ell_\infty \to R$ defines a bounded additive function $\hat{V}$ on the field (Z, Σ) of subsets of the integers Z as follows:*

$$\forall A \subset Z, \hat{V}(A) = V(\alpha^A) \tag{18}$$

where α^A is the "characteristic function" of the set A, namely the sequence defined by

$$\alpha^A = \{\alpha_g^A\}_{g=1,2\ldots} \text{ such that}$$
$$\alpha_g^A = 1 \text{ if } g \in A \text{ and } \alpha_g^A = 0 \text{ otherwise.} \tag{19}$$

Example 4 *Typical purely finitely additive set functions on the field of all subsets of the integers, (z, Σ), are the lim inf function on ℓ_∞, defined for each $\alpha \in \ell_\infty$ by*

$$\lim\inf(\alpha) = \lim_{g=1,2\ldots}\inf\{\alpha_g\}. \tag{20}$$

Recall that the lim inf of a sequence is the infimum of the set of points of accumulation of the sequence. The "long run averages" function is another example: it is defined for each $\alpha \in \ell_\infty$ by

$$\lim_{K,N\to\infty}\left(\frac{1}{K}\sum_{g=N}^{K+N}\alpha_g\right) \tag{21}$$

It is worth noting that a purely finitely additive set function ϕ on the field of subsets of the integers (Z, Σ) cannot be represented by a sequence of real numbers in the sense that there exists no sequence of positive real numbers, $\lambda = \{\lambda_n\}$ which defines ϕ, i.e., there is for no λ such that

$$\forall A \subset Z, \phi(A) = \sum_{n \in A}\lambda_n.$$

For example the lim inf: $\ell_\infty \to R$, defines a purely finitely additive set function on the integers which is not representable by a sequence of real numbers.

11.4. Proof of Theorem 1

Proof. To establish the existence of a sustainable preference $W: \ell_\infty \to R$, it suffices to exhibit a function $W: \ell_\infty \to R$ satisfying the two axioms. For any $\alpha \in \ell_\infty$ consider

$$W(\alpha) = \theta\left[\sum_{g=1}^{\infty}\delta^g\alpha_g\right] + (1-\theta)[\lim\inf\{\alpha_g\}_{g=1,2}],$$
$$\text{with } 0 < \delta < 1, \text{ and } 0 < \theta < 1.$$

W satisfies the axioms because it is a well defined, non-negative, increasing function on ℓ_∞; it is not a dictatorship of the present (Axiom 1) because its second term makes it sensitive to changes in the "tails" of sequences; it is not a dictatorship of the future (Axiom 2) because its first term makes it sensitive to changes in "cutoffs" of sequences.

The next task is to show that the following welfare criteria do not define sustainable preferences: (a) Ramsey's criterion, (b) the overtaking criterion, (c) the sum of discounted utilities, (d) lim inf, and (e) long run averages (f) Rawlsian criteria and (g) basic needs.

The Ramsey's criterion defined in (6) fails because it is not a well defined real valued function on all of ℓ_∞, and cannot therefore define a complete order on ℓ_∞. To see this it suffices to consider any sequence $\alpha \in \ell_\infty$ for which the sum in (6) does not converge. For example, let

$$\alpha = \{\alpha_g\}_{g=1,2\ldots} \text{ where } \forall_g, \alpha_g = (g-1)/g.$$

Then $\alpha_g \to 1$ so that the sequence approaches the "bliss" consumption path $\beta = (1, 1, \ldots, 1, \ldots)$. The ranking of α is obtained by the sum of the distance between α and the bliss path β. Since $\lim_{N\to\infty}\Sigma_{g=1}^{N}(1-\alpha_g) = \lim_{N\to\infty}\Sigma_{g=1}^{N}1/g$ does not converge, Ramsey's welfare criterion does not define a sustainable preference.

The overtaking criterion defined in (9) is not a well-defined function on ℓ_∞, since it cannot rank those pair of utility streams $\alpha, \beta \in \ell_\infty$ in which neither α overtakes β, nor β overtakes α. Figure 1 exhibits a typical pair of utility streams which the overtaking criterion fails to rank.

The long run averages criterion defined in (10) and the lim inf criterion defined in (20) fail on the grounds that neither satisfies Axiom 2; both are dictatorships of the future.

Finally any discounted utility criterion of the form

$$W(\alpha) = \sum_{g=1}^{\infty}\alpha_g\lambda_g \text{ where } \forall_g, \lambda_g > 0, \text{ and } \sum_{g=1}^{\infty}\lambda_g < \infty$$

is a dictatorship of the present, and therefore fails to satisfy Axiom 1. This is because

$$\forall\gamma \in \ell_\infty \text{ s.t. } \sup_{g=1,2\ldots}(\gamma_g) \le 1, \text{ and } \forall\varepsilon > 0,$$

$$\exists N > 0, N = N(\varepsilon): \sum_{g=N}^{\infty}\gamma_g < \varepsilon, \tag{22}$$

and therefore, since

$$W(\alpha) > W(\beta) \Rightarrow \exists\varepsilon > 0: W(\alpha) - W(\beta) > \exists\varepsilon,$$

then by (22)

$\exists N > 0$ such that $\forall\sigma, \gamma \in \Omega$, $W(\alpha^K, \sigma_K) > W(\alpha^K, \gamma_K)$, $\forall K > N$.

The function W thus satisfies the first part of the definition of a dictatorship of the present, i.e.

$$W(\alpha) > W(\beta) \Rightarrow$$
$$\exists N,\ N = N(\alpha, \beta): \forall_\lambda \sigma \in \ell_\infty$$
$$\text{with } \|\gamma\| \le 1 \text{ and } \|\sigma\| \le 1,$$
$$W(\alpha^K, \gamma_K) > W(\beta^K, \sigma_K), \forall K > N.$$

The reciprocal part of the definition of dictatorship of the present is immediately satisfied, since if $\forall \sigma, \gamma \in \ell_\infty$ such that $\|\alpha\| \le 1$, $\|\beta\| \le 1$, $W(\alpha^K, \sigma_K) > W(\alpha^K, \gamma_K)$, and obviously this implies $W(\alpha) > W(\beta)$. Therefore W is a dictatorship of the present and violates Axiom 1.

Finally the Rawlsian welfare criterion and the criterion of the satisfaction of basic needs do not define independent sustainable preferences: The Rawlsian criterion defined in (7) fails because it is not sensitive to the welfare of many generations: only to that of the less favoured generation. Basic needs has the same drawback. □

11.5. Proof of Theorem 2

Proof. Consider a continuous independent sustainable preference. It must satisfy Axioms 1 and 2. There exists a utility representation for the welfare criterion $W: \ell_\infty \to R$, defining a non-negative, continuous linear functional on ℓ_∞. As seen above in Example 3, (18) and (19), such a function defines a non-negative, bounded, additive set function denoted $\hat{W}$ on the field of subsets of the integers Z, (Z, Σ).

Now we utilise the representation theorem of Yosida and Hewitt (1952) and Yosida (1974), which establishes that every non-negative, bounded, additive set function on (S, Σ); the field of subsets Σ of a set S, can be decomposed into the sum of a non-negative measure μ_1 and a purely finitely additive, non-negative set function μ_2 on (S, Σ). It follows from this theorem that $\hat{W}$ can be represented as the sum of a countably additive measure μ_1, and a purely finitely additive measure on the integers Z. It is immediate to verify that this is the representation in (11). To complete the characterisation of an independent sustainable preference it suffices now to show that neither λ or ϕ are identically zero in (11). This follows from Axioms 1 and 2: We saw above that discounted utility is a dictatorship of the present, so that if $\phi \equiv 0$, then W would be a dictatorship of the present, contradicting Axiom 1. If on the other hand $\lambda \equiv 0$, then W would be a dictatorship of the future because all purely finitely additive measures are, by definition, dictatorships of the future, contradicting Axiom 2. Therefore neither λ nor ϕ can be identically zero.

Consider now a preference which is sustainable but not necessarily independent. Then by Axioms 1 and 2 it defines a continuous function $W: \ell_\infty \to R$, which need not be linear. However, for each $\alpha \in \ell_\infty$, it is possible to find a continuous linear function $V^\alpha: \ell_\infty \to R$, such that $V(\alpha) = W(\alpha)$ for which the previous proof applies. This completes the proof of the theorem. □

11.6. Proof of Theorem 3

Statement of Theorem 3:

Consider a sustainable optimum growth problem

$$\text{Max}_{\alpha \in \Omega} W(\alpha_g), \tag{23}$$
$$\text{where } \alpha_g = \{u_g(x_g)\}_{g=1,2\ldots} \in \Omega \subset \ell_\infty.$$

where Ω is the set of all feasible utility streams and W is an independent sustainable preference. By Theorem 2 W must be of the form:

$$W(\alpha) = \sum_{g=1}^{\infty} \lambda_g \alpha_g + \phi(\alpha), \forall \alpha \in \ell_\infty, \tag{24}$$

where $g, \lambda_g > 0, \sum_{g=1}^{\infty} \lambda_g < \infty$, and $\phi \neq 0$ is a purely finitely additive independent measure on Z. Assume that there exists a unique solution to problem (23), denoted α^* and called a sustainable optimum, with welfare value $W^* = W(\alpha^*)$. Assume also that there exist a unique solution, denoted β^* and called a discounted optimum, for the problem of maximising over the same set Ω the discounted utility

$$\text{Max}_{\alpha \in \Omega}(U(\alpha))$$
$$\text{where } U(\alpha) = \theta\left(\sum_{g=1}^{\infty} \lambda_g \alpha_g,\right) \tag{25}$$

which is the first term defining the preference W in (24). Then in general the sustainable optima α^* cannot be approximated by a sequence of feasible utility streams $\{\beta^n\}_{n=1,2\ldots}$ which approximates the discounted optimum β^*, i.e. for all such sequences

$$\lim_{n \to \infty}\left(\theta \sum_{g=1}^{\infty} \lambda_g \beta^n\right) \neq \text{Max}_{\gamma \in \Omega}\left(\theta \sum_{g=1}^{\infty} \lambda_g \gamma\right).$$

This is true for any sequence of "discount factors" $\{\lambda_g\}_{g=1,2\ldots}$ satisfying $\forall g$, $\lambda_g > 0$ and $\sum_{g=1}^{\infty} \lambda_g < \infty$.

Proof. I define a family of optimal growth problems, each with a welfare function of the form (24), and each having a feasible set $\Omega \subset \ell_\infty$, all satisfying the conditions of the Theorem. For each problem in this family, the optimum α^* cannot be approximated by a sequence which approximates the optima β^* of discounted utility functions of the form (25). This is true for any discount factors $\lambda: Z \to R$ which satisfy $\forall g, \lambda_g > 0$, $\Sigma_{g=1}^{\infty} \lambda_g < \infty$.

The set of feasible utility streams Ω is as follows:

$\Omega = \{\alpha \in \ell^+_\infty : \alpha = \{\alpha_g\}_{g=1,2...} \text{Sup}_g(\alpha_g) \leq 1$ and

$\exists \varepsilon > 0$, and integers N and K such that
if $\alpha_g \geq \varepsilon \forall g \leq N$ then $\alpha_g = 0 \forall g > K + N$,

while if $\alpha_g < \varepsilon \forall g \leq N$, then $\alpha_g \geq \varepsilon, \forall g > K + N$.

Each set of parameters ε, N and K define a different feasible set of utility streams Ω.

If the welfare function W is a discounted utility of the form (25), then there exists ε, N and K such that the discounted optimum $\beta^* = \{\beta^*_g\}_{g=1,2...} \in \Omega$ satisfies

$\beta^*_g = 1$ for $g \leq N + K$, and $\beta^*_g = 0$ for $g > K + N$.

The sustainable optima α^* is quite different when in the definition of W, (24), the purely finitely level independent measure ϕ has most of the "weight", i.e., when $\theta \sim 0$. Indeed, for $\theta \sim 0$, the sustainable optimum α^* satisfies

$\alpha^*_g \geq \varepsilon$ for $g > K + N$.

Since both α^* and β^* are unique, and

$\| \alpha^* - \beta^* \| \geq \varepsilon > 0$,

it is clear that a sequence $\{\beta^n\}$ which approaches β^* cannot approach also α^*. This completes proof of the theorem. □

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Discussant's Comments

David G. Victor*

My intervention will reflect on the first three papers from two angles: First I will review the main points of each of these three papers and offer my main critiques on each individually, with special attention to those aspects most relevant for this working group of IPCC and for the design of international agreements on climate change. Because we already have an agreement on climate change—the Framework Convention on Climate Change—my remarks will be especially directed to the relevance for that agreement and future protocols. Second I will consider the papers as a whole, and the proceedings of this conference, and make four points that cut across the particular papers.

Throughout my intervention I will use the terms "fair" and "fairness", but this conference and these papers have abundantly shown that there are many terms. I am avoiding the term "equity" because it has so many other misleading meanings; notably it shares a root with "equal". Our vision of what is fair might be a system of pure equality, but it might not, as Henry Shue and others have noted. Another suitable term might be "justice", but I also avoid that because it implies for many that judicial organs occupy a primary position in determining and enforcing justice. Within international law, especially international environmental law, the key elements of law are primarily international agreements. The contents of agreements and thus the extent to which they reflect different ideas of justice are determined by negotiation and politics and only partially (sometimes not at all) by judicial organs. Thus I will stick with "fairness" as a coherent and understandable term, and the IPCC might be advised to do the same. What fairness means in practice is not easy—the plurality of "fairness" ideas is in part the subject of the conference—and its role in the machinery of international agreements is primarily the subject of this panel.

Overview and Critiques of the Papers Individually

Farhana Yamin has traced the deep and legitimate basis for considering fairness as a principle in international law, and she has shown that the application of fairness criteria is closely circumscribed by the laws, precedents and principles that apply in any particular case. When criteria of fairness have been applied, notably by the International Court of Justice (ICJ), it has only been when multiple legal interpretations are possible. Fairness helps break ties and International law tips in the direction of fairness, but fairness does not drive the interpretation of international law.

Considerations of fairness are also evident in negotiated treaties, including international environmental treaties. The international legal extravaganza of the last two decades—the negotiation and conclusion of the Law of the Sea Treaty—clearly embodies considerations of fairness in its provisions. Notably, Farhana surveys three major global environmental regimes—on ozone depletion, biodiversity and climate change—and finds a trend towards greater explicit inclusion of fairness. All three regimes include mention of fairness in the text and clearly in the substantive provisions. The Climate Change Convention includes the most extensive set of fairness criteria. However, what "fairness" narrowly means in the Convention is difficult—Farhana suggests that an advisory opinion and/or interpretation of key cases could help clarify this.

My main critique concerns whether the importance of fairness as a concept in international law has been overstated in its applicability to the Climate Convention. Fundamentally the Convention is a negotiated document, and thus it is unlikely that any robust and useful interpretation of what is fair, even within the confines of statements about fairness within the Convention itself (e.g. Article 3), is possible except by negotiation. It is unlikely that the ICJ would be willing (or qualified) to make an interpretive statement, and at present the Convention does not have any machinery for dealing with and interpreting cases so as to develop a case law of interpretation on what is legally "fair" under the Convention. There is possibility of such a machinery under Article 13, and I will return generally to the question of legal machinery later.

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Henry Shue begins with a global cap on greenhouse gas (GHG) emissions and then explores the implications of deciding fair shares for each party under that cap. An unavoidable feature of the world economy is that a considerable quantity of GHG emissions is necessary for every person to lead a minimally decent life. This is not an egalitarian view, but only that each person should be allocated not less than the necessary minimum (which he does not define).

Next he applies this metric of fairness to the concept of Joint Implementation (JI) and the possibility that emissions controls could be made through JI bilaterally, rather than through a multilateral agreement such as the Framework Convention on Climate Change (FCCC). He suggests a variety of different types of JI and indicates whether each is likely to benefit rich or poor nations, but in practice I suspect it is difficult to say anything systematic about JI because so much depends upon the prices and the circumstances of the particular case. His conclusions on JI note that some forms of JI might result in increased emissions but still could be beneficial—i.e. undercutting his premise that there needs to be a global cap on GHG emissions. I also think the premise is not robust, but he clearly shows a number of interesting conclusions that stem from thinking about fair allocation and JI schemes starting from the premise.

Finally, he offers several conclusions about JI and fairness, two of which are directly relevant to the current debates. First, any JI trade must not violate the standard of minimally necessary GHG emissions, and thus each trade must be checked on an individual basis to ensure conformity. He does not note that virtually every economist that has observed market mechanisms in practice, would argue the opposite because individual oversight interferes in free and vigorous markets and introduces uncertainty. With this in mind we can predict future debates between philosophers and economists, and those advocates and countries who side with each, about the proper design and operation of JI—in terms of slogans, it will be a classic "equity" vs "efficiency" debate. Henry's second conclusion follows from the first: JI must be part of an international framework and criteria lest the market run amock and undermine fairness. JI advocates agree that there must be an international agreement to set emissions controls—otherwise a viable market will not exist—but economists and Henry will differ on how far that agreement must go. The free market economists will argue that the agreement should be minimal; Henry, and those who are now engaged in the debate over JI criteria in the FCCC, argue for a more expansive role.

My main critique of his paper is twofold. First, the premise of a global cap is problematic in policy terms because it could be that more loosely managing GHG emissions would be a lot cheaper and fairer; this is partially recognised in the paper, and not necessarily crucial to Henry's argument because actually most of his claims hold whether the cap is tight or loose—what is crucial is that countries (and, by extension, people) live by the agreement and not violate the cap or other standard. The second criticism is more serious and is the problem of operation. I don't see, and Henry doesn't offer, a way to quantify the basic needs concept, and thus the major policy recommendation on JI—that each JI trade be subject to review to ensure that it doesn't violate the basic needs criterion—is inoperable. That might suggest that JI itself is inoperable except in obviously compliant cases, which could be a conclusion drawn by extending the paper along these lines but not one that Henry currently draws. It is a problem either for putting Henry's concept into operation or for the JI concept on a grand scale; as I see it they are not compatible.

Alex Alusa and colleagues argue that the Vienna Convention for the Protection of the Ozone Layer (Vienna Convention) and the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) offer useful precedents for the design and operation of the Climate Convention despite the fact that the climate issue is much more complex than ozone depletion. In particular they note the role of UNEP in coordinating actions that put this issue on the international legal agenda and resulted in the Vienna Convention (and later the Montreal Protocol). They emphasise five factors that make the Vienna Convention and Montreal Protocol effective: the role of the Convention in promoting organised scientific research; the fact that the Vienna Convention was a Framework Convention and designed for addition of protocols at a later date; that periodic scientific assessments of the ozone depletion issue along with flexible provisions within the Montreal Protocol to allow amendments and adjustments in light of the latest scientific evidence; the explicit inclusion of fairness concerns, both in the 10 year delay allowed for developing countries and through the Multilateral Fund, which pays the incremental cost of complying with the Protocol; and incentives for developing countries to become parties, such as preferential access to technology and markets and avoiding trade restrictions against non-parties.

To different degrees the Climate Convention includes similar measures, and by implication Alex and his colleagues suggest that areas where the Climate Convention deviates from the Vienna/Montreal model that it would be wise to bring it back into line, in particular: there is a need for an ongoing mandate for independent scientific assessment, clearer rules about financial and technology transfer, and better incentives to join and implement the agreement. They also note that the Montreal Protocol has provisions for dealing with non-compliance, and imply that this could also be helpful for the Climate Convention.

My main criticism of the paper is that the link is not shown between the success story of Vienna/ Montreal and which factors that Alex and his colleagues discuss actually contributed to that success, and to what degree. They describe these factors and they describe the success, but they don't actually demonstrate that the factors caused success. There were many other factors at work, especially at the domestic level and within major chemical firms, and demonstrating cause and effect is actually very complex. An enormous academic literature has grown up around this case that argues a variety of factors and explain the outcomes. In the case of this paper, what evidence is there that the science was actually used in setting and revising the targets, and is it clear that the science had an effect because of the machinery and organisation within the Convention and Scientific Assessment bodies, as Alex and his colleagues claim? Demonstrating cause and effect is especially crucial in this case because so many people see the Convention/Protocol model—especially because of its use in the successful efforts to control ozone depletion but also because of its use in the regional seas programme—as *the* best form of international negotiation. Thus the debate over what makes the Vienna/Montreal experience effective, and what has made it fair for developing countries, applies to that case but also has enormous value in interpreting this precedent for current and future international environmental negotiations. I will return to this general issue of the form of international environmental law later.

Four Points

1. North-South and other dimensions of fairness

All of the major recent global environmental treaties distinguish between developed and developing countries, and thus evaluations of these treaties will automatically focus primarily on the different treatment of North-South broadly. Furthermore, any conference that discusses fairness in global warming will also appropriately focus on the big dimension of fairness: between North and South. Thus we are naturally led to thinking about fairness in North-South terms.

What matters most in agreements is what is actually implemented, and when we turn to that issue it is clear that fairness is multi-faceted—it applies within the North and within the South—and the boundaries between North and South erode. Mexico has more in common with the US, especially after its first decade of cohabitation under the North American Free Trade Agreement, than it does with Chad.

In the climate case this is illustrated by efforts within the European Union (EU) to implement an EU-wide target to freeze emissions at 1990 levels. That has unravelled (for now) because poor EU members (notably Greece, Ireland, Portugal, and Spain) argued that they should be allowed to increase emissions (and avoid some costs of emissions control) while the other richer EU members reduced emissions below 1990 levels and the Union overall met its target. The UK, especially, saw otherwise and this principle of burden-sharing—widely applied in other areas of EU policy—fell apart. The point is that fairness issues become acute in implementation, and we are just beginning to see the battles over what is "fair" in practice, and how it compares with principle. At the domestic level, many industrialised countries are contemplating energy taxes to thwart carbon dioxide and finding, to different degrees, that these taxes are regressive and thus unfair by most measures. Greenhouse policy will be built on top of existing social networks and political tradeoffs, and as these vary from country to country we will see many different applications of "fairness". We think of the EU as a relatively successful regional grouping, but the difficulty even in that context of arriving at a fair distribution portends conflict in implementation of the fairness ideals.

In short, fairness is relevant not only broadly in the world but also in detail. Further, even if the Convention itself is not viewed as fair, issues of fairness will arise as countries struggle to implement the Convention, both in terms of what is fair *vis* their trading and regional partners as well as what is fair within the country. These are hardly new points, but I urge the writing team to keep it in mind when they take their broad view and review of the concepts of fairness.

2. What kinds of expert advice are useful?

In some senses the IPCC has evolved to a rather strange state. It is a mechanism for gaining expert consensus and providing some kinds of expert advice relevant for the Framework Convention on Climate Change (FCCC) but also more broadly for the society as a whole, the Commission on Sustainable Development, and perhaps for other

Conventions where their subjects overlap with climate change. My sense is that the link should be most direct to the FCCC but the Convention is mostly at the state of implementing and elaborating its current provisions, for which the big ideas discussed at this meeting and throughout IPCC are mostly irrelevant—it is not that they are unimportant but only that they are not connected to the problems of the Convention. The IPCC might help with the review of the adequacy of the commitments, as required under the Convention, but at best the IPCC will be only broadly relevant; it could play a larger role if there is major change in the science, but that is unlikely.

I intend this not as a criticism of the IPCC but rather to open up the discussion of relevant disciplines and to reflect on what kinds of expertise would be really useful to the FCCC right now, and how they relate to implementing concepts of fairness. Recall that Farhana gave a large potential role for judicial interpretation in clarifying and implementing fairness principles in the Convention. And Alex and his colleagues suggested that institutions for regular scientific advice could make an agreement more effective and, further, that a mechanism for handling non-compliance can help the agreement resolve implementation failures in a detailed way. Both Farhana and Alex stress the role in handling real cases—Farhana in their role of offering interpretations, and Alex in their role of adequately resolving detailed problems of non-compliance. Henry also stresses the role of cases in his advice that JI be monitored on a case-by-case basis. If a regime is active then the number of cases will be too large to be handled by the Conference of the Parties (COP), so what kinds of mechanisms are best for handling and interpreting cases? The Montreal Protocol Implementation Committee is only one of many models—others include the IMF surveillance and review, various similar functions within multilateral development banks, the ILO review process, the panels under the GATT and associated Codes (now integrated into the dispute settlement provisions of the World Trade Organisation). None of these precedents applies perfectly, but they illustrate the large body of relevant experience—some of it environmental, most of it not—that is useful in the context of elaborating the machinery of the Climate Change Convention. Indeed, the Convention is in the next months beginning just that process as it interprets and considers a possible case mechanism that might be established under Article 13.[1]

The point remains that fairness matters most during the process of implementation, and if parties take implementation seriously then questions and problems will arise, and some of these must be handled by international machinery. When that machinery operates it applies and interprets the law and standards, including fairness, and thus a major means of putting fairness into practice under international agreements is designing the proper machinery to allow fairness (and other principles) to be applied in particular cases, which are valuable not only because they interpret the particular problem at hand but also because they can create precedents. This is hardly the high profile North-South broad concerns about fairness, nor concerns about the different impacts of climate change upon different countries, but it is an area where careful reviews of past experience can lead to low level but ultimately important policy advice. It is the type of research usefully done by political scientists, lawyers, and organisational analysts—these groups are not extensively represented in the IPCC.

Again, these points are hardly new. At this stage I urge the writing team to consider that fairness matters most in implementation, and one area where policy is actually malleable—and thus expert advice actually matters—is on the details of designing that implementation machinery. Obviously the most important machinery is at the national level and should be left to national governments and non-governmental actors, but some international training programmes are helping in that area. At the international level there is also room for useful work, and if devices such as an implementation committee, non-compliance procedure, dispute panels, or the envisioned Article 13 process get underway within the Climate Convention, they could prove the major way that fairness issues are interpreted, except for the periodic broader revision of the Convention and/or its protocols through political negotiations.

3. Some unconventional costs and fairness consequences of the climate enterprise

Some concepts of fairness stress freedom of individual or national action. That is, a situation is fair if it maximises the ability of people and their governments to do what they

[1]The exact text of Article 13: "The Conference of the Parties shall, at its first session, consider the establishment of a multilateral consultative process, available to Parties on their request, for the resolution of questions regarding the implementation of the Convention". (Having entered into force in March, 1994, the first session of the Conference of the Parties (COP) will be held in March, 1995.)

want to do, provided that it does not infringe upon others. Henry's concept of minimally necessary emissions echoes this idea, as does the concept of basic needs discussed elsewhere at this conference. Usually when this vision of fairness is applied to the climate change problem the analyst arrives at the conclusion that strong emissions controls are necessary because climate change affects other people and therefore violates this measure of fairness.

But it is possible to arrive at nearly the opposite conclusion. The climate enterprise—by which I mean the suite of meetings such as this one, negotiating sessions, climate research programmes, and all activities now underway that would not be in place if it were not for fears of global warming—is expensive. I estimate that this meeting of 125 people cost $250,000 in direct costs, double that if we include the value of participants' time, extra organisational costs to UNEP, translators and some other indirect costs. If Working Group III holds ten meetings—one for each chapter—then the cost of its report is $5 million (There is some fat in the number, but that can be used to pay for other meetings, review costs, etc.) Is some or all of that $5 million better spent on other items? I don't know the costs of negotiating sessions, but each one is minimally $5 to $10 million (not including the cost of NGO participation), and this summer will be the tenth. Most importantly, fears of global warming are causing significant shifts in lending priorities because multilateral development banks and bilateral aid programmes are adding global warming concerns—i.e. decarbonising energy, reducing non-carbon greenhouse gases, and adapting to climate change—to their lending and granting criteria.

I am not arguing that this activity is unnecessary. Clearly, at least some is crucial to keep abreast of climate change and help ensure the society is not caught by surprise. But the question I am asking is what are the consequences for fairness, especially for the developing countries. The developing world did not put the global warming issue on the international agenda, may find it difficult to control that agenda because much of it is driven by domestic environmental groups in the North, and yet nonetheless are dragged along into climate politics by the need to participate in meetings and, crucially, the pressure to change development policies to be greenhouse friendly? I suggest two types of answers:

(a) *Opportunity Costs:* What could be done with these resources if they were not spent on climate actions? I have already implied that the climate enterprise could be an unwanted burden, at least viewed from a global social perspective, on the least developed countries, whose development priorities may lay elsewhere. The opportunities lost for domestic policy that is now directed towards climate change and away from something else represent the cost to fairness—in other terms the infringement upon fairness.

(b) *Positive Externalities:* To what degree will preparing for climate change help countries and individuals address other problems they would need to face anyway? There are externalities from climate policy that are positive. Some examples:
   - Policies to adapt to climate variability and drought are broadly well served by efforts within the climate enterprise to stress adaptation;
   - Policies to control the loss of biodiversity and forests may help also control net emissions of carbon into the atmosphere, and thus reduce contributions to global warming;
   - Policies to reduce some kinds of local air pollution, especially through fuel switching to cleaner lighter fuels (i.e. away from coal and towards oil and especially methane) also reduce contributions to global warming. These are the kinds of policies that should be given extra weight when planning for climate change and abating greenhouse emissions because they infringe the least upon autonomy.

To close let me note that this is an extreme view, and one obviously not shared by most people inside the climate enterprise, but one that should be taken seriously. It is not obvious that acting on global warming—or acting in the ways that the climate enterprise is now proceeding—is the right response when we worry about fairness. Especially where the agenda is controlled by the North but it is the South whose development priorities, including basic human needs, might be redirected away from their indigenous priorities, the world needs to be careful. Indeed there are fairness consequences of what is being done right now and where the world is headed right now. These have not been examined by most analysts because they are thinking too far into the future—on the fairness consequences for various stylised systems of targets and timetables, tradeable permits, carbon taxes, and financial transfers. It is customary to claim that at present there are few consequences for fairness on the developing countries because they have only minimal requirements under the Convention, but that conclusion may be wrong because already their development priorities are affected.

My advice to the writing team is to note these alternative conclusions and to highlight that the policy implications are, at minimum, a strong need to ensure that the climate enterprise works in areas that overlap with existing development priorities. This practical point is derived from worrying about the externalities of climate policies; most economists would argue the same from the vantage of economic efficiency—here I argue the same but from the vantage of fairness. Crucially, if our vision of fairness is to promote autonomy then we need to be careful that the climate enterprise does not take on a life of its own and drag others into unwanted actions. If the climate enterprise does drag countries and people into unwanted actions—and frankly that is one of the purposes of the climate enterprise—then it should do so with a clear vision of what actions square with the concept of fairness because the very act of dragging violates at least some ideas of fairness.

4. How should future commitments to control climate change be embodied in international law?

This is the most important policy question facing the international negotiators right now. The paths chosen will centrally determine both how the Convention is implemented as well as how concepts of fairness are incorporated. We are embarking on a potentially multi-billion dollar enterprise, so we should be careful. The negotiators face some of the following choices:

- *Hard vs Soft Law:* The prescription of most climate policy advocates is the need for "legally binding measures", i.e. hard law, because they don't trust governments. In fact, the evidence for this advice over softer alternatives—such as flexible standards and codes of conduct—is mixed. Governments who negotiate hard law realise that binding measures are binding and thus negotiate looser commitments, but in soft law regimes they are more willing to take bolder steps. Nonetheless, soft law statements induce some accountability—at times reinforced by NGOs and other watchdogs—and soft law is more flexible. Ever shifting detailed concerns of fairness that arise during implementation will require adjustment of the agreement, and it may prove easier to make the necessary adjustments within a soft regime than in a hard one. Even if we adopt Henry Shue's suggested cap on GHG emissions—and perhaps embody that in a hard law instrument—the bulk of the climate regime could still usefully operate in a softer legal context.
- *Convention/Protocol Model:* That the Climate Convention is a Framework Convention immediately implies that the next steps are to elaborate protocols, perhaps by parsing the different aspects of the climate issue into separate protocols that cover forestry, some industrial sectors, perhaps scientific research, etc. The models are many, but negotiators especially have in mind the Vienna Convention/Montreal Protocol model, as well as the Long Range Transboundary Air Pollution agreement and the regional seas agreements. What lessons have been learned from those models? In some sense the particular form of hard law—whether as part of the Convention or as a separate agreement—doesn't matter. But Convention/Protocol thinking does unfortunately lead the analyst to break up the climate problem into its component parts, as has clearly happened in acid rain and in some of the regional seas regimes. But that is dangerous as a model for climate change because it erodes the over-arching feature of the climate problem: that all causes and consequences are interconnected, and further that the commitments to slow and adapt to global warming will weave across most other commitments in international environmental and economic law. Few have thought whether the Convention/Protocol model can deal with such problems.
- *Targets and Timetables:* One conclusion that many draw from the Montreal Protocol experience, and other international environmental agreements that embody targets and timetables, is that hard targets and timetables are an essential component of effective treaties, and that if targets are set properly (e.g. with differential obligations and delays, as shown by Alex and his colleagues in their paper) they can address concerns about fairness. The evidence for this view is actually quite thin, and especially for issues that must be managed within a context of large uncertainty and shifting socio-economic context—which is abundantly true for global warming emissions controls—

looser targets, perhaps in the context of a soft law agreement, may be appropriately more flexible. Targets may even be the wrong approach because it isn't clear where in the chain of economic activity to codify controls. Emissions targets put controls at the end of the chain and then leave governments to implement them backwards, controlling the underlying causes of emissions and hoping that their measures somehow add up to meeting the target. But there are other options that could be employed, including:

- Agreements on property rights, both in defining new property rights (i.e. extended versions of JI) and in urging countries generally to better define property rights for common pool resources. It is fashionable to bash economists, but one area where their advice is especially helpful is the insight on getting prices right and property rights properly defined.
- Measures chosen to overlap with other development priorities including:
  - adaptation measures, such as reducing vulnerability to storm surges, flooding, and extreme weather events;
  - measures that overlap with biodiversity policies, such as sustainable forestry;
  - measures that overlap with management of marginal lands and thus also overlap, in some areas, with desertification policies.

These choices will affect whether and how the agreement addresses fairness issues, and as I have implied, given the magnitude of these decisions there is remarkably less careful attention to the nonconventional alternatives. Three cultures are especially dangerous: the culture of hard law, which thinks that hard law measures are the best and only way to get real change in government policy; the culture of targets and timetables, which thinks that hard emissions control are the best way to invoke policy change; and the culture of conventions and protocols, which maintains that a succession of legal instruments attached to a global convention is the best way to organise international law. All three cultures stand on thin reeds of evidence.

The point is simply that the best design of an international agreement on global warming is far from clear, and in the absence of some probing questions about the current conventional wisdom the global warming agreement is headed for a hard law, convention/protocol, targets and timetables approach. My advice to the writing team is to note that the structure of international commitments and the organisation and evolution of international law will obviously affect the role of international law in controlling the climate problem, including how fairness issues are included. The relevant disciplines for studying this problem are law and political science and thus may lie outside the scope of IPCC, but there are some tentative answers in this area, and in any case it is asking the questions that is most important right now. The critical choices for the agreement are coming in the next few years, and some questions from IPCC could help ensure that there is at least a debate about the right track for the Convention's evolution.

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