UNEP

International Resource Panel

INTERNATIONAL TRADE IN RESOURCES

A biophysical assessment

Acknowledgements

This report has been produced for the UNEP-hosted International Resource Panel (IRP). It is the result of the efforts of several expert members of the IRP as well as external expertise. We thank the key authors of the report: Marina Fischer-Kowalski, Monika Dittrich, and Nina Eisenmenger. We would also like to thank the following for their valuable contributions: Paul Ekins, Julian Fulton, Thomas Kastner, Karin Hosking, Heinz Schandl, Jim West, and Thomas O. Wiedmann.

We would also like to thank those that provided their valuable time in carrying out the external peer review of the report: Vangelis Vitalis, Heike Baumueller, Jan Weinzettel, Dabo Guan, Kuishuang Feng, and Chen Hin Keong. Special thanks to Julia Kolar of Institute for Social Ecology at University of Klagenfurt in Austria for essential support in data verification.

We would also like to extend our thanks to International Resource Panel member Edgar G. Hertwich, who acted as Peer Review Coordinator for this report.

The UNEP Secretariat Team provided essential support, especially Shaoyi Li, Madhuvantthe, Christina Bodouroglou and Abraham Pedroza.

The full report should be referenced as follows:
UNEP (2015), *International Trade in Resources: A Biophysical Assessment*, Report of the International Resource Panel.

Design & Layout: Marie Moncet at Sourible; Printing: CLD, UNESCO, France
Cover photos ©: Sludge G, flickr; Sajid Pervaiz Fazal, flickr;
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ISBN (Full Report): 978-92-807-3486-7

UNEP

International Resource Panel

Summary for Policy Makers

INTERNATIONAL TRADE IN RESOURCES

A biophysical assessment

Produced by the International Resource Panel

This document highlights key findings from the report, and should be read in conjunction with the full report. References to research and reviews on which this report is based are listed in the full report.

The full report can be downloaded at www.unep.org/resourcepanel/publications.

Preface

World trade has expanded vastly over past decades, fuelled by progressive liberalisation and rapidly increasing demand for resources. Between 1980 and 2010 the value of trade increased more than six-fold and the volume of trade more than doubled in order to meet the needs of a growing and more prosperous global population.

Increased trade is indispensable in overcoming localised limits to the supply of natural resources. However, it is precisely the corresponding impact it has on raising global production and consumption which is worrisome from an environmental standpoint. Trade also raises distributional concerns, by shifting environmental problems related to extraction and processing activities from high-income importing to low-income exporting nations.

Tasked with building and sharing knowledge on how to improve management of the world's resources, UNEP's International Resource Panel (IRP) turns its attention to the world trading system and its implications for global resource efficiency. In this report entitled *International Trade in Resources: A biophysical assessment*, the IRP examines how efficient the current system of world trade is in distributing resources from the geographical locations of supply to the locations of demand. By examining trade from a biophysical (versus an economic) viewpoint, the authors of the report seek to assess whether or not trade allows commodities to be obtained from countries where their production requires fewer resources and generates a smaller amount of wastes and emissions.

The particular report was prepared by the IRP's Working Group on Environmental Impacts, with the aim to enhance knowledge on the nature, location and size of the environmental impacts of trade. It provides a comprehensive synthesis of the latest scientific evidence on the ''upstream resource requirements'' of international trade. These refer to the materials, energy, water and land used along the production chain of traded commodities, and function as a proxy for the ecological effects of trade.

By reviewing the existing literature on the topic, the authors hope to aid understanding of the complex inter-relationship between trade and environment. In doing so, they seek to provide answers to a series of questions relating to the degree and distribution of trade dependency; the magnitude and composition of upstream resource requirements; as well as the implications of trade for global resource efficiency.

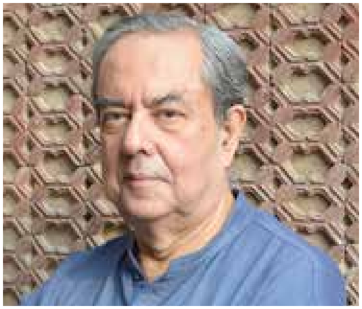
The study highlights the heightened vulnerability of the global trading system, as its balance relies on ever fewer resource producers.

With regards to estimating upstream resource requirements, the report draws attention to the difficulties involved. Estimates of upstream materials, water and land range widely, from 40 to 400 per cent of traded materials, depending on methodology and resource. Nevertheless, some common conclusions can be drawn. For instance, accounting for upstream resources embodied in trade accentuates patterns of unequal exchange, as the difference in resource use between developed countries and developing countries becomes much more pronounced.

As for the central question of whether international trade improves or worsens the efficiency of global resource use, the answer remains inconclusive. Yet, the fact that upstream requirements have been shown to be rising over-proportionally in recent decades, means that there are likely other factors which prevent a potentially more environmentally efficient allocation of resources through international trade.

On the whole, the report contributes to the discussions on resource use and resource efficiency. It presents an authoritative, policy-relevant assessment that sheds light on the implications of global trade for environmental sustainability and resource scarcity. It provides knowledge required by policy-makers to help tackle the negative environmental consequences of trade and craft trade policies in support of environmental objectives.

Dr. Ashok Khosla,
New Delhi, India



Co-Chairs,
International Resource
Panel (IRP)

September 2015

Dr. Janez Potočnik,
Ljubljana, Republic of Slovenia

Foreword

International trade has long been recognized as an important enabler of economic growth and prosperity, permitting countries to meet rising demand for resources that are not available or affordable domestically. Benefits such as increased production, cost efficiency, competition and choice are evident, but their environmental impacts are more ambiguous. A better understanding of the complex interactions involved is needed to shape policy that can maximize synergies and minimize trade-offs, particularly given the recent surge in trade flows.

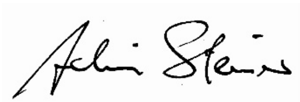
International Trade in Resources: A biophysical assessment makes a significant contribution to this understanding. While examining trends in the international trade of natural resources, it focuses on upstream requirements such as materials, energy, water and land used at the point of extraction or production. This approach is useful because it takes account of the additional resources consumed in the country of origin and the waste and emissions left behind once the goods are exported.

Looking back over the past three decades, the report provides evidence of the rising upstream requirements due to a general increase in trade levels, a greater share in the trade of high-processed goods, declining metal ore grades and the need to feed a growing population from land with diminishing productivity. It concludes that these factors are likely to offset any potential resource efficiency and environmental benefits associated with extraction and production processes.

Although there is no definitive conclusion as to whether trade improves or worsens the global efficiency of resource use, its distributional impacts are more apparent. Trade typically shifts the environmental burden from high-income and densely populated importing countries to low-income and more sparsely populated exporting countries. The extraction and processing of resources for export depletes natural assets, while increasing waste, emissions, loss of biodiversity, land degradation and water pollution. Likewise, domestic efforts to curb greenhouse gas emissions in one country may be negated by increasing imports from, and transferring investments, to countries with weak legal commitments to reduce emissions.

However, such damaging impacts on the environment can be limited by clear policies, bilateral or regional trade agreements, border adjustment mechanisms, and subsidies and free emissions allowances for domestic firms.

Therefore, while explicit policy analysis is beyond the scope of the report, it provides essential knowledge for anyone seeking to develop a supportive policy framework that can increase both trade and environmental benefits, through efficient production, resource management and access to green technologies and goods.



Achim Steiner
UN Under-Secretary-General
UNEP Executive Director

Content

Credit: Neil Kremer, flickr

1. Introduction

Purpose & structure of report

The International Resource Panel (IRP) was established by the United Nations Environment Programme (UNEP) in 2007, to help build and share the knowledge needed to shift towards a more sustainable use of resources and a ‘‘green economy’’ path.

Prepared by the Panel, *International Trade: A Biophysical Assessment* focuses on resource use and environmental impacts of world trade, and adds novel information to discussions on sustainable resource use and resource efficiency, decoupling and dematerialization. Through a comprehensive review of the existing literature on global commodity trade assessed from a biophysical (as opposed to a standard economic) perspective, the assessment aims to provide insights into the implications of trade for global resource use efficiency. The starting point for this assessment is that human well-being is intrinsically linked to the availability and quality of natural resources such as energy, materials, water and land. But resources are distributed unequally across the globe, owing to a confluence of factors that include geography, climate and population density.

International trade has played a central role in meeting the rising global demand for natural resources in the past century by enabling access to resources that are inaccessible or are no longer sufficiently available within countries. However in the context of its contribution to improving global environmental and resource efficiency, international trade would have to allow for the extraction of resources and production of commodities in places where smaller amounts of wastes and emissions are produced. In order to determine whether world trade leads to a more efficient allocation of resource extraction and use, this study examines the so-called ''upstream resource requirements'', in terms of materials, energy, water and land, of traded commodities. These refer to the additional resources used in the upstream production process of traded goods but ''left behind'' as wastes and emissions at the location of extraction or production. Indicators of upstream resource requirements of traded goods can therefore capture the consumption-related resource uses along the production chain and attribute an environmental burden to importing (consumer) countries.

Overall, evidence presented in this study points to rising upstream resource requirements of trade. This means that trade does not necessarily contribute to global resource efficiency, because there may be factors at play (such as decreasing ore grades or declining productivity of land) which prevent a potentially more resource efficient allocation of extraction and production processes through world trade.

In terms of policy implications, any policies on trade – whether targeted at restructuring, reducing or stimulating trade activities – will also influence upstream flows and hence global resource use and efficiency. Such policy analysis (for instance, examining which trade policies and agreements would limit resource overexploitation, waste and environmental destruction), whilst important, is nevertheless beyond the scope of this report.

With respect to its structure, this publication is organized into four subsequent chapters. They focus on:

- The importance of trade in supplying countries with resources, including patterns of trade dependence and how these change over time
- The upstream resource requirements of traded commodities, in terms of materials, energy, water and land
- The upstream requirements by type of traded commodity, differentiating between biomass, metals and fossil fuels
- Summary findings, including conclusions on the impact of trade on global resource efficiency

Key findings and main messages

The central messages of this study can be summarized as follows:

- Of all material resources extracted and used worldwide, about 15 per cent are traded. As traded volumes have increased faster than the amount of extracted resources over the past three decades, this means that the overall importance of trade for supplying countries with resources has increased.
- Dependence on the world market for delivering vital commodities is increasing sharply around the world, and with it the vulnerability of the global trading system: its balance relies on ever fewer resource producers.
- Recent decades have seen changes in long-term patterns of ''unequal exchange'' between high- income industrial and developing countries. While high-income countries continue to be the main recipients of resources via trade, emerging economies such as China have become major importers. On the supply side, a number of high-income OECD and non-OECD as well as upper-middle income countries have become important global suppliers of materials, partly prompted by twenty-first century rising resource prices. Population density (versus income) is increasingly shaping structural patterns of trade.
- A combination of methodological approaches – based on material flow analysis, life cycle assessments and multi-regional input-output models – are used to assess resource efficiency of international trade and the changes it undergoes over time.
- Estimating the upstream resource requirements – in terms of materials, water and land – of traded commodities is useful in determining the environmental impacts of trade. This is, however, a challenging task, with estimates ranging from 40 to 400 per cent of traded materials, depending on resource and estimation method. When accounting for such resources embodied in trade, the difference in resource use between high-income (and high consumption) countries and lower-income countries is much more pronounced than the picture given by direct trade.
- On the whole, trade could, in theory, be resource efficient insofar as it allows commodities to be obtained from countries/ locations where their production requires fewer resources and generates fewer environmental impacts than in others.

- However, in practice, there are numerous mechanisms – including higher trade levels (especially, of higher-processed goods), declining ore grades and decreasing energy returns upon energy investment (EROEI), higher food demand and diminishing land productivity – which further increase the upstream resource requirements of trade.

- As a consequence, the answer as to whether international trade improves global resource efficiency is currently inconclusive. Further research efforts underway aimed at improving methods and indicators dealing with the physical properties of trade are likely to provide valuable insights in this respect.

Credit: Land Rover Our Planet, flickr

2. The dynamics and importance of trade in resources

Monetary versus physical trade flows

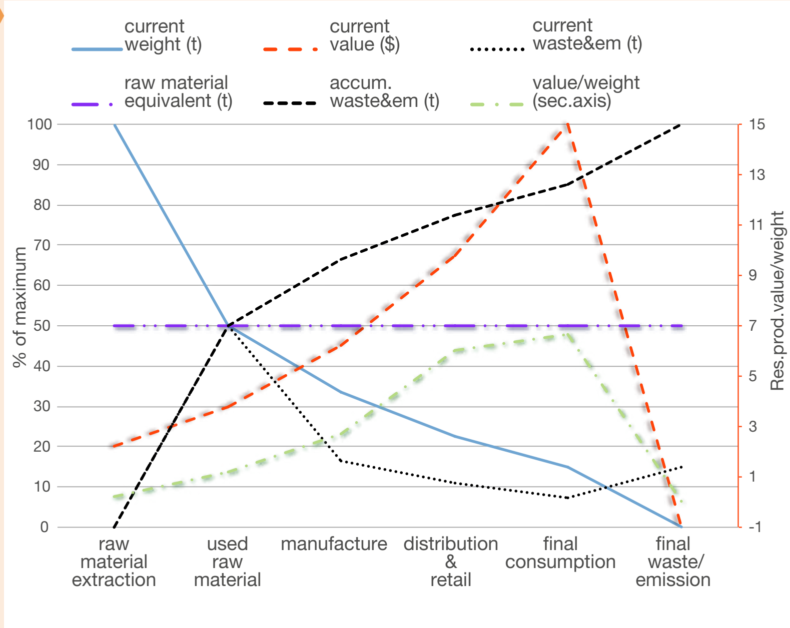
Recent decades have witnessed a dramatic increase in the global demand for natural resources, while (economic or environmental) limits to the supply of a number of resources have become ever more visible. Increasing world trade is an effective means of overcoming local and regional supply shortages to meet growing demand. The resulting contribution of trade to boosting production and consumption, though praised *economically*, is *environmentally* much more ambiguous – precisely because of the growth impact. Trade can also lead to adverse distributional outcomes, by shifting the environmental burden of extraction and production of resources to poorer nations.

In assessing the efficiency of the current system of world trade in distributing resources from the geographical locations of supply to the locations of demand, it is therefore critical to distinguish between economic efficiency and resource and environmental efficiency. While the former is measured through *monetary* indicators, the latter relies on *physical* indicators as it relates to the amount of resources and the environmental impacts linked to trade. This report is concerned with resource efficiency, and therefore focuses on *physical* trade flows.

The key to understanding the difference between a monetary and a physical representation of trade flows lies in understanding the opposing trends of weight and value in the life cycle of commodities. With each step in the life cycle, the part of the product's input that has been used is transformed into wastes and emissions, and the product itself gets lighter, while increasing in value (see Figure 1). Depicting trade in physical terms holds greater explanatory power for assessing the environmental burdens of traded materials and where they occur; however, it is a highly complex task. Each kilogram of materials traded may have a long history along which resources were used, resulting in different environmental burdens, and materials may already have been traded several times, leading to problems of double counting.

Figure 1

Material use, wastes and value added along a product life cycle from extraction, across production, consumption and deposition



Model assumptions: from raw material extraction to used raw material 50% of material is discarded [difference between total material requirement (TMR) and domestic extraction (DE)]; at each further stage, 33% of weight is lost to wastes/ emissions. From one stage to the next, the value increases by a factor of 1.5, but drops to zero after consumption (stylized facts). The raw material equivalent (RME) corresponds to used raw material (DE). (see Haas et al., 2015)[1].

1. Haas, W., Krausmann, F., Wiedenhofer, D., Heinz, M., 2015. How circular is the global economy? An assessment of material flows, waste production and recycling in the EU and the world in 2005. Journal of Industrial Ecology forthcoming.

Trends in international trade in resources

The preceding discussion, distinguishing between economic efficiency and resource and environmental efficiency and the respective monetary and physical measurements of trade, lays the ground for a more informative analysis of recent trends in the international trade of commodities.

International trade has grown significantly in recent decades, with global trade volumes increasing over six-fold in monetary terms,[2] or more than doubling in physical terms, between 1980 and 2010 (see Figure 2). The amount of global resource extraction and use has also increased, though to a lesser degree, which demonstrates the rising overall importance of trade for supplying countries with the resources they need.

Of all material resources extracted and used worldwide (65 billion tons in 2010), about 15 per cent (10 billion tons) is traded. While seemingly small, this proportion increases to around 40 per cent when resources indirectly associated with trade (that is, used in the production process, but not physically included in the traded good) are included.[3]

In terms of the material composition of trade, natural resources or commodities at a very low level of processing dominate physical trade flows, with manufactured products amounting to only 20 per cent of trade volumes (while in monetary terms they amount to 70 per cent). The lion's share of trade is taken up by fossil fuels (about 50 per cent), followed by metals (about 20 per cent) and biomass (about 10 per cent) (see Figure 2).

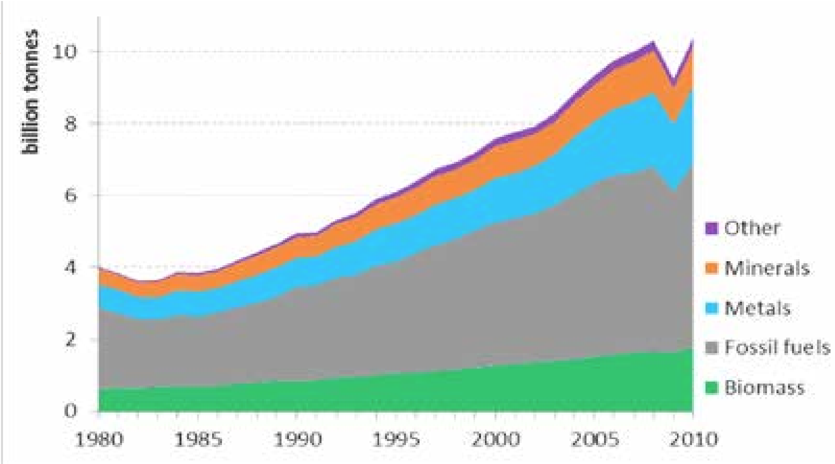
Around half of the volume of extracted fossil fuels and metals – which are key ingredients of industrial production – is reallocated through trade. In contrast, biomass, such as food, is mainly supplied domestically. However, if the domestic supply does not suffice to feed the population (the case in several countries in the Middle East, but recently also in China), trade becomes critical.

2. UNCTAD, 2013. UNCTADstat [WWW Document]. URL http://unctadstat.unctad.org/EN/ (accessed 1.3.13).

3. Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2013. The material footprint of nations. Proceedings of the National Academy of Sciences 201220362.

Figure 2

Physical trade according to material composition, 1980–2010



Physical trade measured as (imports + exports)/2. Manufactured products (about 20 per cent of total trade) are assigned to the resource categories they consist of proportionally. The group of "other" materials could not be assigned – it consists largely of (mineral) water and other beverages.

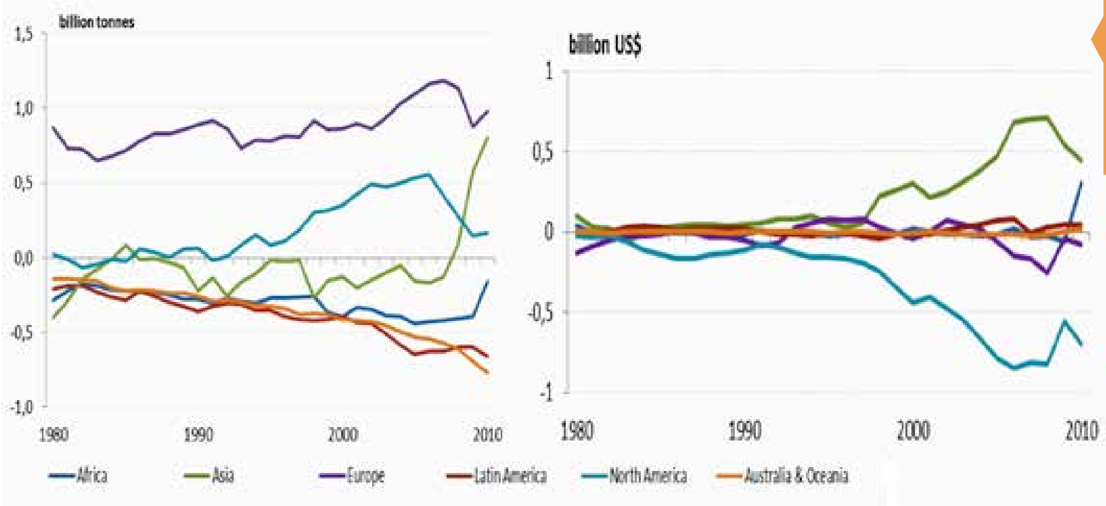
4. Dittrich, M., 2012. Global Material Flow Database: Trade, Version 2012. [WWW Document]. URL http://www.materialflows.net/home/

Trade balances of countries provide valuable insights into the geographical distribution of suppliers and consumers in the world economy. In economic terms, a country's trade balance is positive when the value of its exports is higher than the value of its imports. In physical terms, a country's trade balance is positive when the weight of its imports is greater than the weight of its exports.

In general, and for clear economic reasons (for example, changes in exchange rates), trade in economic terms is fairly balanced. In earlier decades, North America was the only world region with a consistently negative monetary trade balance, mirrored by a consistently positive trade balance in Asia (mainly driven by China). All other main regions balanced around zero (see Figures 3). With respect to physical trade volumes, deviations from zero are much more common. Physically, Europe has had a consistently positive trade balance (that is, has imported higher volumes than it has exported) and lately so have North America and Asia. Negative physical trade balances have been the norm in Africa, Latin America and Australia/Oceania.

Figure 3

Trade balances by continent in physical (left) and monetary (right) terms, 1980–2010



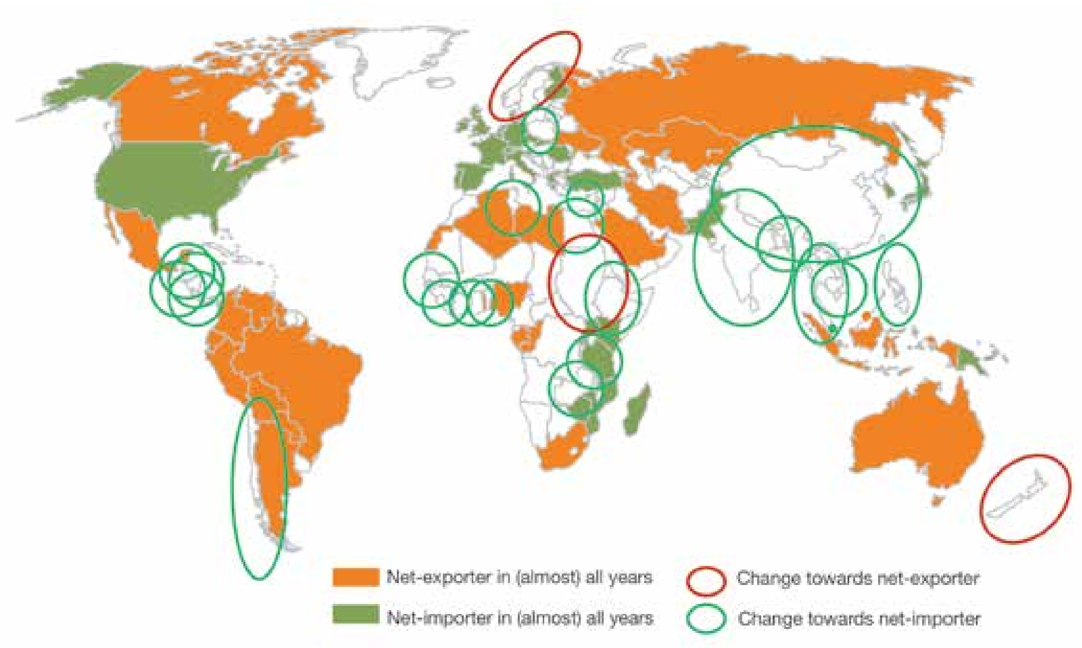
Sources: Physical terms: (Dittrich, 2012),[5] monetary terms: (UN, n.d.)[6]
Please note: While monetary trade balances are counted as exports minus imports, physical trade balances are counted as imports minus exports. The physical trade balance of a region represents only inter-regional trade; intra-regional trade balances out.

5. Ibid
6. UN, n.d. UN Comtrade I International Trade Statistics Database [WWW Document]. URL http://comtrade.un.org/ (accessed 11.12.14).

In 2010, 30 per cent of all countries supplied materials to world markets, while 70 per cent of all countries net imported them. South American, Scandinavian, West and Central Asian countries as well as Canada, Australia and the South-East Asian islands have been the largest suppliers of materials. With respect to imports, the United States, Japan and West European countries have remained major importers throughout the past three decades. Several countries have shifted roles from being net exporters to becoming net importers, among them the world's most populous economies , China and India (see Figure 4). While the number of net exporters is decreasing, they are increasing their export volumes in order to meet growing global demand.

Figure 4

Persistence and changes in net importing and net exporting countries, 1962–2010



Source: (Dittrich et al., 2012)[7]

7. Dittrich, M., 2012. Global Material Flow Database: Trade, Version 2012. [WWW Document]. URL http://www.materialflows.net/home/

Dependence on the world market for delivering vital commodities has sharply increased around the world since 1980, as most countries have increased their imports faster than their domestic resource extraction. Import dependency has increased with respect to all material categories, but is highest for fossil fuels and metals. In 2008, more than 100 countries imported more than half of their fossil fuel requirements and 97 countries imported more than half of their metal requirements. Dependence on biomass imports is generally higher for countries with unfavourable bio-geographical conditions. This is the case in 17 countries, mainly small islands and West Asian countries such as the Seychelles or

Kuwait, which imported more than half of their biomass requirements. Of note, however, is that rising global interdependency goes hand-in-hand with increased vulnerability of the global trading system, as it comes to rely on ever fewer exporters. A reduction in one or more exporter's capacity due to depletion of sources or to political/military reasons, could, for instance, have a major destabilizing effect.

Throughout the twentieth century, global trade patterns were largely determined by countries' economic development. High-income industrial countries imported a large amount of resources from countries with low income levels and exported a smaller (but more valuable) amount of processed goods to one another. However, this pattern of ''unequal exchange'' appears to be changing. In recent decades, high-income non-OECD countries (mainly oil-exporting countries) and some high-income OECD countries (such as Australia, Canada and New Zealand), and upper-middle income countries (such as Russia, Brazil and South Africa) have become important exporters of materials. This structural change has in part been driven by rising resource prices in the new millennium, with extraction and export of resources becoming more attractive and affording resource-rich countries political and economic power. At the same time, lower-middle income countries (most markedly, China) have changed their status from supplier to importer, and increased their net imports dramatically (See Figure 5).

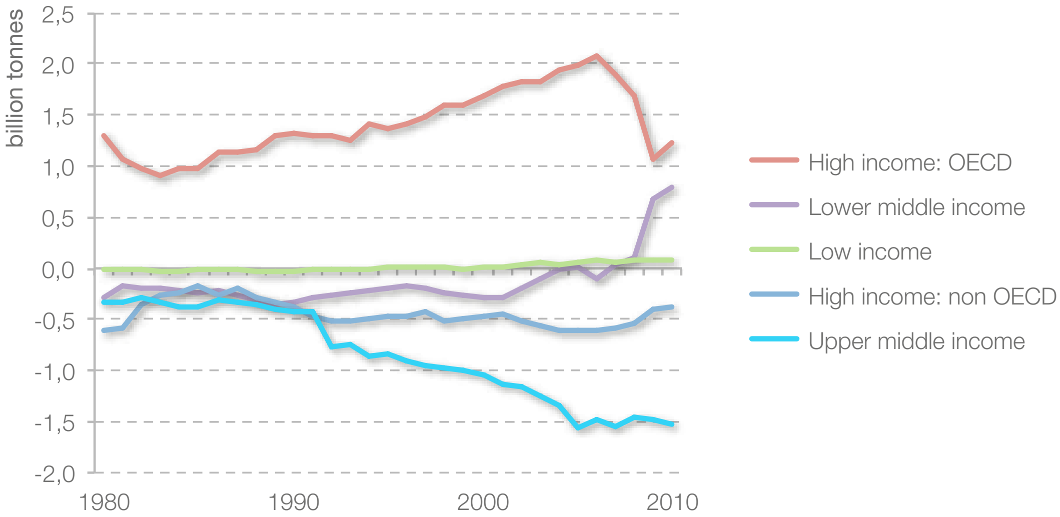
Whilst these trends show that relations between high-income and developing countries have become somewhat more symmetrical, the role of high-income countries as the main recipients of resources via trade remains unchanged. Europe has the most pronounced positive physical trade balance of all the continents (see Figure 3), and OECD countries in general consistently score high on physical trade balances (see Figure 5).

Although it is obvious that income continues to shape the role countries occupy in international trade, it appears that its influence is waning. Instead, another variable – namely, population density – seems to be gaining traction (Krausmann et al., 2008).[8] Increasingly, sparsely populated countries are supplying materials, more or less irrespective of their income. The material volumes reallocated from sparsely to densely populated countries tripled between 1980 and 2008. Other important determinants of trade patterns include resource endowment, technological development and the possibility of accessing previously inaccessible resources (such as the exploitation of shale gas).

8. Krausmann, F., Fischer-Kowalski, M., Schandl, H., Eisenmenger, N., 2008. The Global Sociometabolic Transition: Past and Present Metabolic Profiles and Their Future Trajectories. Journal of Industrial Ecology 12, 637–656. doi:10.1111/j.1530-9290.2008.00065.x

Figure 5

Countries' physical trade balances (PTB) by income group, 1980–2010



Source: (Dittrich, 2012);[9] Assignation according to (World Bank, 2012).[10] Overall, the overwhelming dominance of high-income, industrial countries in world trade has given way to more trade between developing countries. In part, this is due to China acquiring a dominant role in world trade. Since the turn of the century, the share of South-South trade has doubled (in monetary terms) and now amounts to around one-third of global trade. The share of North-North trade, on the other hand, has shrunk, while the North exports more to the South than ever before (Lee et al., 2013).[11]

9. Ibid
10. World Bank, 2012. Indicators I Data [WWW Document]. URL http://data.worldbank.org/indicator/ (accessed 1.2.13).
11. Lee, B., Preston, F., Kooroshy, J., Bailey, R., Lahn, G., 2013. Resources Futures. Royal Institute of International Affairs, London, UK.

Credit: Hans Splinter, flickr

3. Upstream resource requirements of traded commodities

In assessing the impact of international trade on global resource efficiency, standard trade statistics have limited explanatory power, as they consider trade flows with the current mass, energy or water content the goods have at the time they cross state borders. However, additional resources have been used in the country of origin for producing the traded goods. Calculating these upstream resource requirements – while distinguishing between materials (including energy fossil carriers), water and land – helps to attribute resource use and environmental burden to the consumer country.

Materials

The past decade has seen intensive research efforts to account for the materials used in the upstream production process of goods but "left behind" as wastes and emissions at the location of extraction or production.

There are two approaches to estimating the upstream material requirements of international trade (also known as ‘‘indirect trade flows’’):

1. an input-output approach (using environmentally extended multi-regional input-output models (MRIO) to trace the amount and kind of resources connected to a country's final demand, and whether they have been imported or extracted domestically)
2. a life-cycle assessment (LCA) approach (using coefficients from life cycle inventories (LCI) of products in order to calculate the upstream requirements of traded goods)

These two approaches can also be combined to form so-called **"hybrid" approaches.**

When it comes to reviewing existing studies that calculate upstream requirements of trade, the fact that they rely upon different methods, system definitions and time frames renders their findings difficult to compare.

Nevertheless, a common finding in the literature is that the difference in resource use between high-income countries and lower-income countries is much more pronounced when trade flows are measured in ''raw material equivalents'' (RME) (that is, the sum of materials traded plus their respective material upstream requirements) rather than as direct flows. Such ''material footprint'' analyses show that, in industrialised countries, the upstream requirements are significantly higher than the physical quantity of trade, leading to an ''outsourcing'' of material use through trade. For emerging economies, the difference is much smaller. In the case of resource-extracting economies, the picture is reversed; their resource extraction includes significant amounts associated with final demand in other countries. Estimated material footprints as calculated by two MRIO models for 42 countries are displayed in Figure 6 below.

Similar results emerge when trade balances based upon raw material equivalents are considered. High-income countries have in the order of 40-100 per cent larger positive raw material trade balances (RTB) (which add upstream resource consumption to the weight of the goods at border) than physical trade balances (PTB). For instance, RTB for EU27 is significantly more positive (more imports than exports) than when measured by PTB (see Figure 7). For low-income countries, the opposite is true.

Findings based on LCA methods show that upstream materials embodied in trade amount to about four times the weight of directly traded products, and have been rising over-proportionally during recent decades (Dittrich, 2010; 2012).[12]

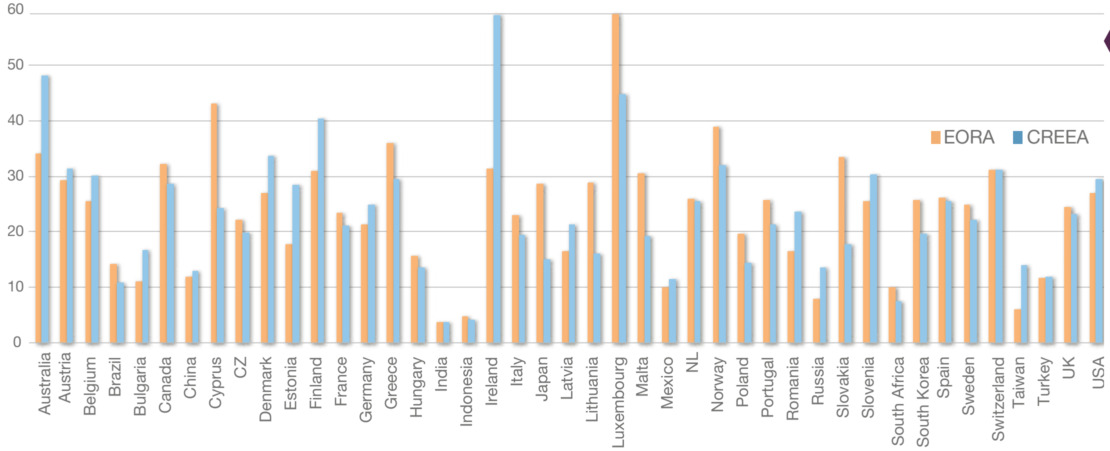
In terms of geographical distribution, Oceania appears as the region with the highest direct and indirect net exports, followed by Latin America. Europe, on the other hand, is the region with the highest direct and indirect imports, followed by Asia.

Overall, the analysis of global flows of upstream material requirements reveals that industrialized countries require raw materials provided by developing countries (mostly of low population density). This, in turn, results in a corresponding shift in the environmental burden related to extraction and processing activities from developed (importing) to developing (exporting) regions.

12. Dittrich, M., 2010. Physische Handelsbilanzen. Verlagert der Norden Umweltbelastungen in den Süden? Dissertation., Kölner Geographische Arbeiten. Universität Köln, Köln.
Dittrich, M., 2012. Global Material Flow Database: Trade, Version 2012. [WWW Document]. URL http://www.materialflows.net/home/

Figure 6

A comparison of material footprint results from Eora and CREEA models

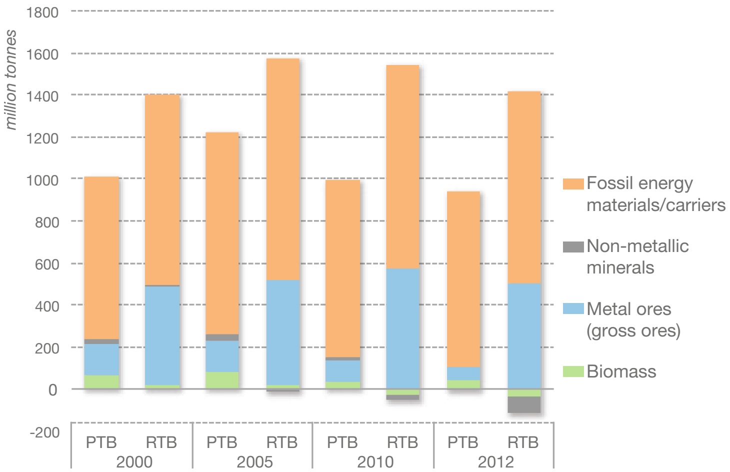


Sources: CREEA: Tukker et al. (2014);[13] Eora: Wiedmann et al. (2013)[14]

13. Tukker, A., Bulavskaya, T., Giljum, S., de Koning, A., Lutter, S., Simas, M., Stadler, K., Wood, R., 2014. The Global Resource Footprint of Nations. Carbon, water, land and materials embodied in trade and final consumption calculated with EXIOBASE 2.1. Leiden/Delft/Vienna/Trondheim.
14. Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2013. The material footprint of nations. Proceedings of the National Academy of Sciences 201220362.

Figure 7

EU27 physical trade balance (PTB) and raw material trade balance (RTB)



Source:
(Eurostat, 2014)[15]

15. Eurostat, 2014. Environmental accounts [WWW Document]. URL http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/introduction (accessed 11.3.14).

Materials

In calculating the magnitude of the environmental burden, studies of energy requirements of trade tend to arrive at similar results. Indeed, the growing importance of international trade has come at an environmental cost of rising upstream energy use and carbon dioxide (CO2) emissions, especially since the turn of the millennium.

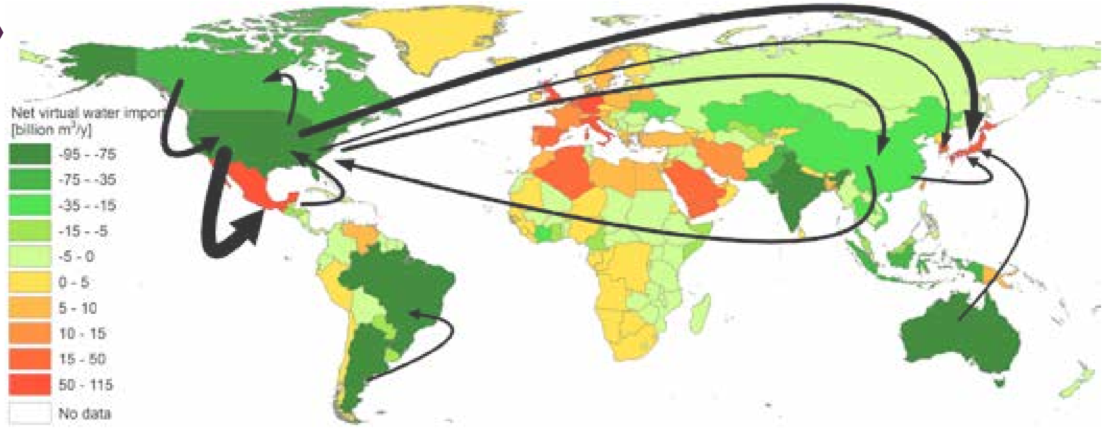
Water

Other studies follow a comparable approach in order to compute the upstream requirements of other resources such as land and water.

Research relating to upstream water use – or so-called "virtual water" – typically focuses on agricultural and livestock products, though increasingly on industrial and energy products also. Analysis of upstream water flows within the context of global trade permits the calculation of how much water a country saves by importing goods that have needed water for their production elsewhere,

Figure 8

Virtual water balance per country and direction of gross virtual water flows related to trade in agricultural and industrial products over the period 1996–2005



Source: Mekonnen and Hoekstra, 2011.[16] Only the biggest gross flows (>15Gm3/y) are shown

16. Mekonnen, M.M. and Hoekstra, A.Y. (2011) National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands.

compared to an estimated water requirement if they had been produced domestically. Therefore, importing food from regions with more conducive climatic conditions, soil quality and/or production technologies, could theoretically lead to increased global water efficiency.

As regards the distribution of virtual water flows, the largest net virtual water flows are from South America to Europe and Asia. In particular, most countries in Europe, the Middle East, and North Africa are net virtual water importers. Japan, South Korea, and Mexico are also notable importers. The largest virtual water exporters are found in North and South America, as well as in South and South-East Asia, and Australia (see Figure 8).

Land

In addition to materials and water, a similar approach can be taken to calculate upstream requirements of land.

Land as a resource cannot be traded physically, meaning that land resources will always be "embodied" in international trade. Research on land resources embodied in trade is comparatively scarce and typically focuses on agricultural and forestry products. In addition to studies that solely measure the amount of land required for a traded product, other studies also capture the productivity of land.

The latter approach includes analysis of upstream land requirements in the ecological footprint tradition, which seeks to translate human consumption levels into demand for biologically productive land (for example, Rees and Wackernagel, 1994[17]). Land requirements are expressed in terms of ''global hectares'', reflecting the area that would have been needed to produce a given product on land of global average productivity. Comparing the calculated ecological footprint to the available land resources provides an indicator of (un)sustainability, and flags up differences in consumption patterns and lifestyles.

Another approach makes use of the indicator human appropriation of net primary production (HANPP) to account for the fact that land can be managed at greatly varying intensities (for

17. Rees, W.E., Wackernagel, M., 1994. Ecological Footprints and Appropriated Carrying Capacity. Measuring the Natural Capital Requirements of the Human Economy, in: Jannson, M. (Ed.), Investing in Natural Capital: The Ecological Economics Approach to Sustainability. Island Press, Washington.

example, Haberl et al., 2007[18]). HANPP accounts for both the amount of land-based products extracted through harvest and human-induced changes in land productivity.

Results from such studies investigating land-use impacts of trade have shown that about 15 per cent of global cropland area is linked to international trade (Kastner et al., 2012).[19] As with other resources, upstream requirements of land have tended to grow faster than directly traded land-based products.

Regions that are sparsely populated (North and South America, Oceania, FSU, and parts of Sub-Saharan Africa) tend to be the main exporters of embodied land, while areas of high population density (Asia and Europe) have the highest imports. Although the trade of land-based products is necessary to balance global demand and supply (particularly, in the case of food), it can also lead to deforestation, land degradation and other environmental problems in the producing and exporting countries.

On the whole, the analysis in this section has focused on the use of upstream resources linked to international trade. However, such analyses can also be extended, for instance, to the use of the upstream labour required for traded products. Approaches calculating ‘‘labour footprints’’ (that is, labour embodied in trade) tend to confirm the previously discussed asymmetry between industrialised and developing countries. Findings show that high income regions/countries such as North America and OECD-Europe import about as much foreign labour as the domestic share of labour for satisfying their domestic consumption, while all other world regions import much smaller shares or hardly any foreign labour (Simas et al., 2014).20 In fact, North America and OECD Europe import more so-called ‘‘bad labour’’ (referring to low-skilled and health-damaging labour) than they employ domestically, while in all other regions the opposite tends to be true. In this way, global inequalities are perpetuated through international trade.

18. Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., Fischer-Kowalski, M ., 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proceedings of the National Academy of Sciences 104, 12942–12947. doi:10.1073/pnas.0704243104
19. Kastner, T., Rivas, M.J.I., Koch, W., Nonhebel, S., 2012. Global changes in diets and the consequences for land requirements for food. Proceedings of the National Academy of Sciences 109, 6868–6872. doi:10.1073/pnas.1117054109

20. Simas, M., Golsteijn, L., Huijbregts, M., Wood, R., Hertwich, E., 2014a. The "Bad Labor" Footprint: Quantifying the Social Impacts of Globalization. Sustainability 6, 7514–7540. doi:10.3390/su6117514

Credit: Jimmy Harris, flickr

4. Upstream requirements by type of traded commodity

At this point a closer examination of upstream requirements of material trade flows is undertaken, differentiating between the main types of traded materials:

- biomass
- metals
- fossil fuels

Biomass

Biomass refers mainly to materials of plant origin, and its predominant use is for human nutrition. Biomass production accounts for by far the largest share of human land-use, with agricultural land comprising almost 40 per cent of the total global land surface (FAO, 2012).[21]

21. FAO, 2012. FAOSTAT statistical database [WWW Document]. URL http://faostat.fao.org/

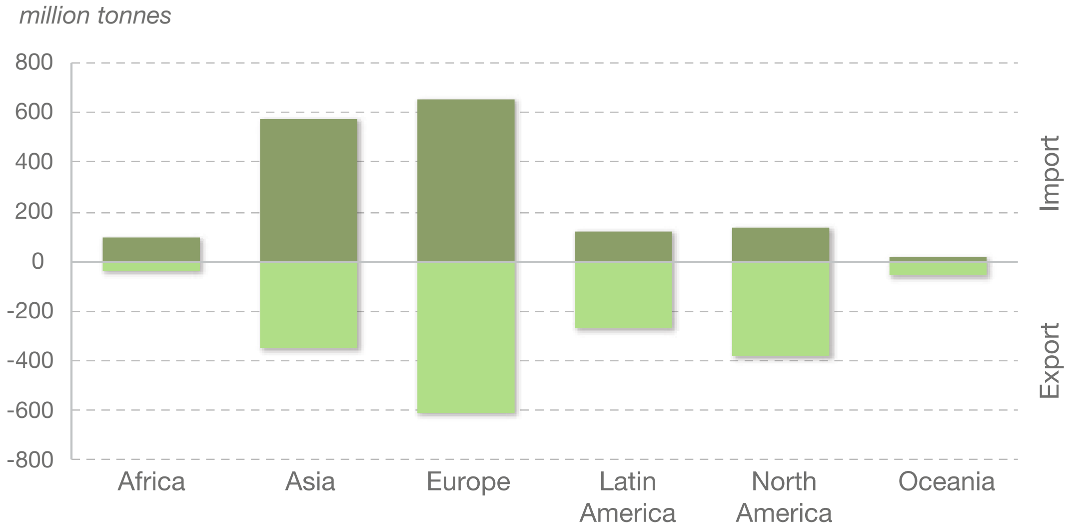
Land resources and the potential for biomass production are distributed very unevenly across the globe. Consequently, trade in biomass products can be important in compensating for such regional differences in per capita land endowment. Indeed, accounts of biomass trade, in general, evidence flows from regions with high per capita land availability to those with low land availability (for example, Erb et al., 2009;[22] Kastner et al., 2011;[23] Haberl et al., 2012[24]).

22. Erb, K.-H., Krausmann, F., Lucht, W., Haberl, H., 2009. Embodied HANPP: Mapping the spatial disconnect between global biomass production and consumption. Ecological Economics 69, 328–334. doi:10.1016/j.ecolecon.2009.06.025
23. Kastner, T., Erb, K.-H., Nonhebel, S., 2011. International wood trade and forest change: A global analysis. Global Environmental Change 21, 947–956. doi:10.1016/j.gloenvcha.2011.05.003
24. Haberl, H., Steinberger, J.K., Plutzar, C., Erb, K.-H., Gaube, V., Gingrich, S., Krausmann, F., 2012. Natural and socioeconomic determinants of the embodied human appropriation of net primary production and its relation to other resource use indicators. Ecological Indicators 23, 222–231. doi:10.1016/j.ecolind.2012.03.027

North America was the largest net supplier of biomass in 2008, followed by Latin America and Oceania. Asia was by far the dominant net importer, followed by Africa and Europe (see Figure 9). This geographical distribution follows patterns of population density, although other factors, such as transportation infrastructure, access to technology and conflicts, also influence production and trade patterns.

Figure 9

Biomass-based commodity trade between countries, by continent, 2008



Source: (Dittrich et al., 2012)

Overall, around 15 per cent of all biomass materials globally extracted are redistributed through foreign trade; this fraction rises to one-quarter if upstream material requirements are included (Bruckner et al., 2012).[25] Upstream resource requirements of biomass materials have also grown faster than directly traded biomass. This trend, however, is not so much a result of growing upstream materials requirements per each ton of products, but is due rather to the growing share of higher-processed biomass products in trade (Regmi, 2001).[26]

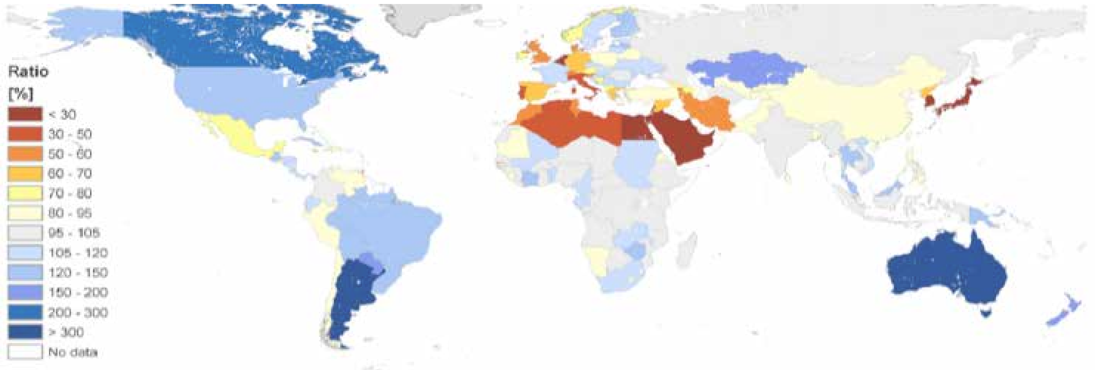
If one looks specifically at the upstream requirements of biomass trade in terms of land, the previously mentioned HANPP indicator is particularly informative, as it also takes into account differences in land-use intensity. Studies of embodied HANPP in biomass trade confirm the finding that sparsely populated regions are the main net exporters and densely populated ones the main net importers, mostly irrespective of development status (Haberl et al., 2009;[27] Erb et al., 2009[28]).

Figure 10 shows, at national levels, the ratio between HANPP occurring on a nation's territory and the embodied HANPP linked to a nation's consumption of biomass products. While blue tones indicate net exports of embodied HANPP, red colours represent net imports, and thus dependency on foreign land resources. The map shows that the Americas and Oceania were the main suppliers of land-based products, whereas many European countries, as well as Japan and Korea and Northern Africa and Western Asia, were importing considerable amounts of embodied HANPP.

25. Bruckner, M., Giljum, S., Lutz, C., Wiebe, K.S., 2012. Materials embodied in international trade – Global material extraction and consumption between 1995 and 2005. Global Environmental Change 22, 568–576. doi:10.1016/j.gloenvcha.2012.03.011
26. Regmi, A. (Ed.), 2001. Changing Structure of Global Food Consumption and Trade. USDA, Washington D.C.
27. Haberl, H., Erb, K.H., Krausmann, F., Berecz, S., Ludwiczek, N., Musel, A., Schaffartzik, A., Martinez-Alier, J., 2009. Using embodied HANPP to analyze teleconnections in the global land system: Conceptual considerations. Geografisk Tidsskrift - Danish Journal of Geography 109, 119–130.
28. Erb, K.-H., Krausmann, F., Lucht, W., Haberl, H., 2009. Embodied HANPP: Mapping the spatial disconnect between global biomass production and consumption. Ecological Economics 69, 328–334. doi:10.1016/j.ecolecon.2009.06.025

Figure 10

Ratio between HANPP on a nation's territory and embodied HANPP linked to a nation's consumption



Source: (Erb et al., 2009)[29]

29. Ibid

In addition to land, the production of biomass goods also involves the use of significant amounts of water. The agricultural sector accounts for as much as two-thirds of global water withdrawal (Shiklomanov, 2000[30]). As regards the upstream water requirements of global agricultural trade, recent estimates range from around 600 to 1,700 km^3 annually, and are rising (Dalin et al., 2012;[31] Hoekstra and Mekonnen, 2012[32]).

30. Shiklomanov, I.A., 2000. Appraisal and Assessment of World Water Resources. Water International 25, 11–32. doi:10.1080/02508060008686794
31. Dalin, C., Konar, M., Hanasaki, N., Rinaldo, A., Rodriguez-Iturbe, I., 2012. Evolution of the global virtual water trade network. Proceedings of the National Academy of Sciences 109, 5989–5994. doi:10.1073/pnas.1203176109
32. Hoekstra, A.Y., Mekonnen, M.M., 2012. The water footprint of humanity. Proceedings of the National Academy of Sciences 109, 3232–3237. doi:10.1073/pnas.1109936109

Moreover, other resources are embodied in biomass trade, including fossil fuels (for fuelling tractors and machinery and producing fertilizers), metals (contained in machinery and rural production sites), and non-metallic minerals (for constructing roads and agricultural buildings).

On the whole, international trade in biomass products is indispensable for promoting global food security, by supplying the necessary nutrition in a number of world regions, especially the Middle East and North Africa. However, biomass-exporting countries can face a disproportional environmental burden. Given its classification as a renewable resource, biomass is not directly threatened by scarcity or exhaustion, but by overuse. This can lead to biodiversity loss, loss of carbon storage capacity, land degradation, water contamination and depletion, and even to a reduction in future agricultural productive capacity.

Metals

In contrast to biomass, metals are non-renewable materials and extraction reduces deposits. Besides such depletion of available resources, metal extraction and processing is linked to manifold environmental problems, ranging from displacement of ecosystems and human settlements, to release of harmful emissions, and overexploitation and contamination of soil and water. In spite of this, past decades have witnessed the continuing extraction and depletion of metal deposits, which has also led to declining ore grades. The latter is of concern, as it is likely to exacerbate adverse environmental impacts and to require even higher inputs of materials (gross ore), energy and water to produce the same amounts of metal.

Geographically, metal deposits are highly concentrated in certain regions. Their uneven distribution across the globe, alongside the limited substitutability of metals, highlights the importance of international trade in allocating metals from countries with available deposits and low (monetary) extraction costs to countries with insufficient domestic sources and/or potentially higher extraction costs. Trade therefore helps meet global demand for metals, whilst contributing to higher global *economic* efficiency.

Assuming trade allows metals to be extracted and processed in those incurring the least environmental damage, it can in theory also lead to higher *environmental* efficiency. Indeed, metal extraction costs depend on some environmental factors (such as ore grades, water and energy costs, or remoteness of the area), even if these are likely to be outweighed by economic and other considerations (such as technological know-how, wage levels, transport infrastructure, energy costs, and environmental and health regulations).

While international trade in metals can result in important economic and even environmental efficiency gains, it nevertheless appears that the environmental burden imposed on extracting and exporting countries is increasing. Metal trade has been increasing rapidly, compared to metal extraction; as much as 40 to 60 per cent of metal extraction is directly or indirectly linked to trade (Bruckner et al., 2012;[33] Wiedmann et al., 2013[34]).

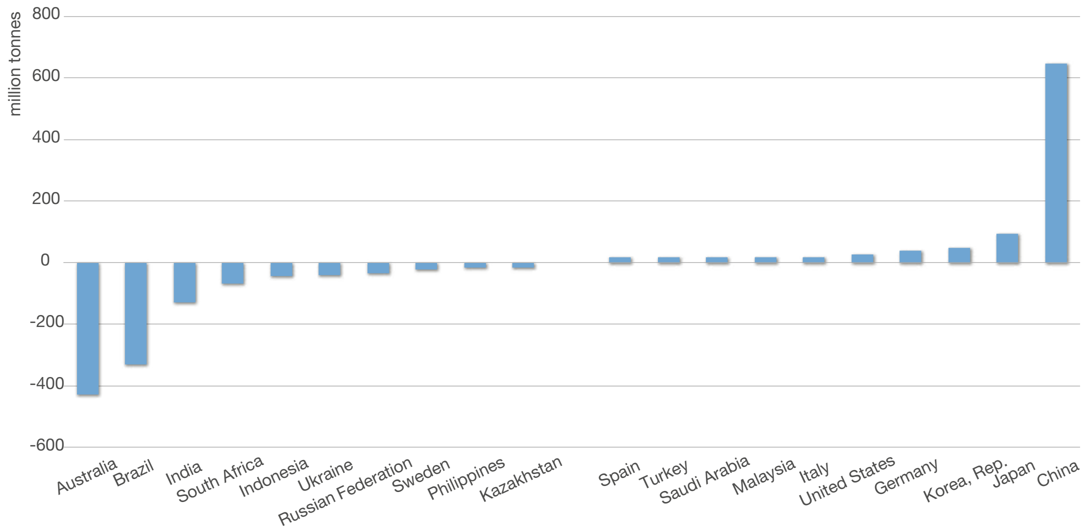
33. Bruckner, M., Giljum, S., Lutz, C., Wiebe, K.S., 2012. Materials embodied in international trade – Global material extraction and consumption between 1995 and 2005. Global Environmental Change 22, 568–576. doi:10.1016/j.gloenvcha.2012.03.011
34. Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2013. The material footprint of nations. Proceedings of the National Academy of Sciences 201220362.

Importantly, research findings show that the upstream resource (material, energy and water) requirements of the metal trade are increasing, and faster than direct trade. This reflects both a change in the physical composition of the metal trade (towards a higher share of metals with high upstream requirements, such as copper and precious metals) as well as the aforementioned average decline in ore grades.

The environmental burden of metal extraction is mainly borne by sparsely populated industrial and developing countries. The dominant metal exporters are countries with abundant (known) deposits and high extraction activity, while the dominant metal importers are mainly industrialized or emerging economies with low or moderate known metal deposits per capita. Asia (in particular China) and Europe are the regions that import most. The main global suppliers are countries like Australia, Brazil, Indonesia, Russia, India and South Africa (see Figure 11).

Figure 11

Top 10 net suppliers and net importers of metals in the year 2010



Source: (Dittrich, 2012)[35]

35. Dittrich, M., 2012. Global Material Flow Database: Trade, Version 2012. [WWW Document]. URL http://www.materialflows.net/home/

Fossil Fuels

With regard to the fossil fuel sector, the availability of abundant and inexpensive energy resources has been seminal in enabling a transition towards modern industrial societies. However, this transition has also come at an environmental cost of rising carbon emissions and accelerant climatic change, caused by the widespread use of fossil energy for heating, cooling, transport and most major industrial processes.

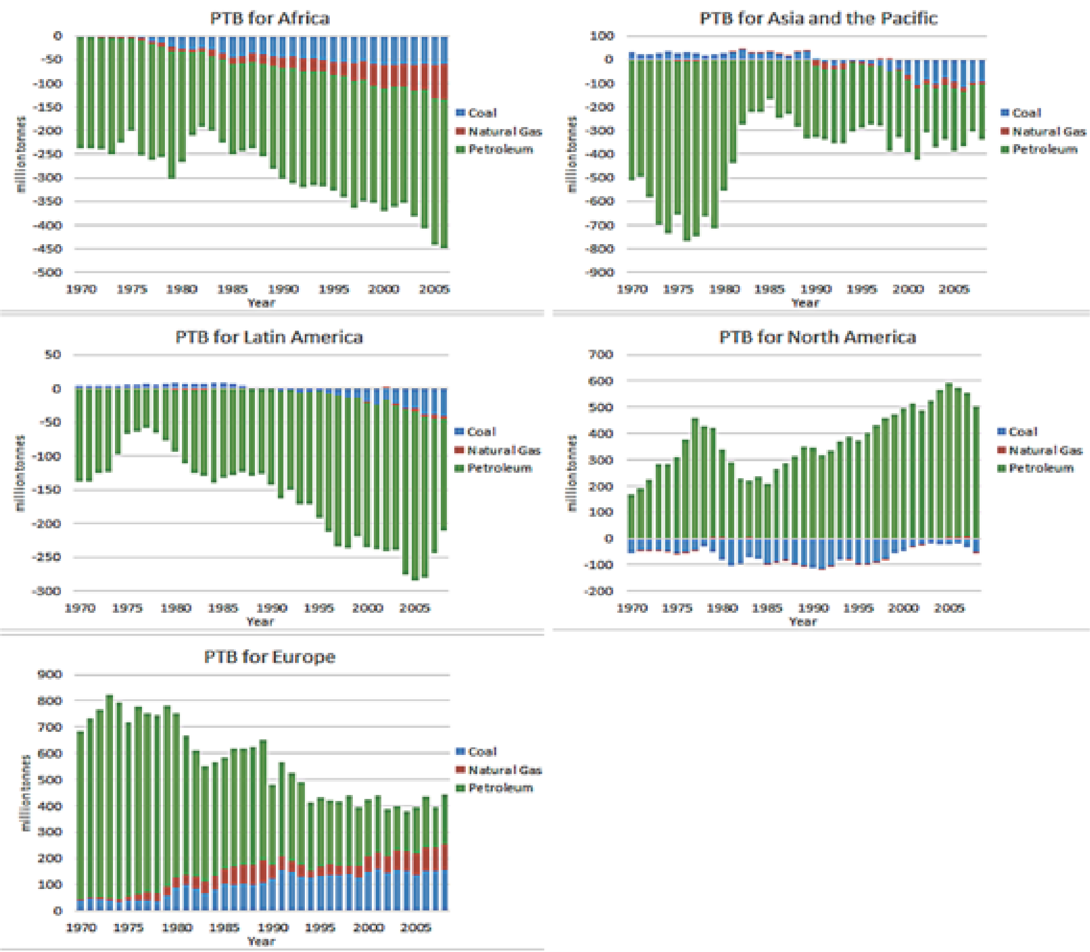
The geographical distribution of fossil fuels (coal, petroleum and natural gas) is perhaps the most uneven among the resources under consideration, with some individual countries accounting for large fractions of the global natural endowment. This is especially the case when the issues of the quality of deposits and the ease of exploitation (and the related concept of energy return on energy invested (EROEI)) are taken into account.

International trade in fossil fuels is therefore fundamental to overcoming mismatches between sources of supply and centres of demand for one of the most important requirements of modern, affluent societies. The economic and strategic importance of trade in fossil fuels is evident when one considers that it has been the main practical alternative to colonialism/war in securing energy supplies. Indeed, threats to continued trade in fossil fuels and its control have contributed to the outbreak and the course of several conflicts over the past half-century.

The extraction and use of fossil fuels has grown by an annual rate of 1.9 per cent since 1970, with coal being extracted both in the highest amounts and with the highest growth rates. Coal is geographically not as concentrated as natural gas and petroleum. By far the largest producer is China, but the largest exporters are Australia and Indonesia. The largest importer of coal is Japan, followed by Korea and India. With regard to natural gas, Russia leads as an exporter, while the main importers are the United States, Japan and Germany. Crude oil is exported mainly by Saudi Arabia and Russia; the United States is the largest importer. Fossil fuel physical trade balances have been strongly positive for Europe and the United States over the past four decades, while all other major world regions have had negative balances (see Figure 12).

Figure 12

Largest exporters and importers of petroleum in 2008, in million tonnes



Source: CSIRO Global Material Flow Database

With respect to upstream requirements of fossil fuel trade, substantial material and energy inputs are needed for the construction and operation of associated infrastructure (ports, ships, pipelines and so on). The raw material equivalent (RME) of the actual trade in fossil fuels (which expresses the total amount of resources – including upstream material requirements – needed to satisfy consumption) represents about 60 per cent of the RME associated with the total consumption of fossil fuels, thereby highlighting the importance of international trade in the fossil fuels sector.

While seemingly very large, the upstream inputs required for trading in fossil fuels are nonetheless thought to be less than would otherwise be the case, if the energy were sourced locally. The most obvious energy requirement pertaining to fossil fuel trade that would not be incurred if the fuel were sourced locally, is the energy required for the international transport of traded fuels. This includes the energy used in international marine bunkers and pipeline transport, and has been calculated as being less than 2 per cent of the energy contained in the traded commodities (IEA, 2011a;36 2011b37). Assessing the possible impact on the upstream requirements of fossil fuels of whether they are internationally traded or locally sourced, will be determined by the specific characteristics of source deposits and extraction/beneficiation processes. It is generally assumed that the lower the EROEI of a fuel source, the higher its upstream material and energy requirements will be per unit. Therefore, the 2 per cent upper estimate of energy used in transport would, for instance, rapidly reduce the EROEI for such energy sources as coal, meaning that international trade would very likely lead to a net increase in upstream requirements. The impact of the 2 per cent impost would still be significant for oil, but less so for natural gas.

Looking ahead, large amounts of fossil fuels will continue to be traded, driven by strong demand and continued industrialisation in developing countries, as well as a further concentration of supplier countries and demand centres. Future demand is likely to remain buoyant, particularly in the presence of widespread and generous fossil fuel subsidies that artificially lower prices, drain state budgets, and increase CO2 emissions. Instead, a policy shift in subsidies and tax exemptions from fossil fuels to renewable energy could support a transition towards a decentralised, renewable energy supply, which would be necessary, in order to reduce greenhouse gases and help avert the catastrophic impacts of climate change.

36. IEA, 2011a. Energy balances of OECD countries.
37. IEA, 2011b. Energy balances of Non-OECD countries.

Credit: DFID - UK Department for International Development, flickr

5. Conclusions

This booklet summarizes the report produced by the International Resource Panel entitled "International Trade in Resources: A biophysical assessment". It focuses on resource use and upstream resource requirements of international trade, in an attempt to shed light on the implications of trade for global resource efficiency. The resources covered are materials (including fossil energy carriers), water and land, across a time period extending from 1980 (or earlier, where possible) to 2010.

On the basis of the existing literature, it seeks to provide answers to the following questions.

1. How important is trade for supplying countries with resources? How is trade dependency distributed, and how does it change over time?
2. Which roles do countries occupy in international trade, where are the centres of use and demand, and where are the locations of international supply of resources? What factors determine this distribution?
3. What are the upstream resource requirements, in terms of materials, water, and land, of traded commodities? How large are they, how are they composed and how do they change over time?
4. Finally, what can be concluded from the answers to the above questions about the contribution of trade to the efficiency of global resource use?

QUESTION 1

How important is trade in supplying countries with resources, and how does dependency on trade change over time?

Trade is vital in enabling countries to overcome the constraints of local resource scarcity, by moving resources from locations of supply to centres of demand. About 15 per cent of all material resources globally extracted and used are *directly* traded, though this proportion rises to 40 per cent for resources *indirectly* associated with trade (that is, used in the production of exports, even if part of those materials never left their country of origin).

Over the past three decades world trade in physical terms rose by a factor of 2.5, while global resource extraction less than doubled. Since trade volumes increased faster than material extraction, this signifies both a lengthening of production chains and the growing importance of trade for supplying countries with requisite resources.

Indeed, dependence on material imports has increased in most economies during the past 30 years, and is particularly high with regard to fossil fuels and metals. During the same period, many countries shifted towards becoming net-importers of resources, whereas very few turned to becoming net exporters. Thus, global interdependency is rising, but at the same time, the vulnerability of the global trading system is increasing: growing demand is being met by a shrinking number of net exporters. If one or more exporters were to see their supplies disrupted owing to resource depletion or for political/military reasons, this could have a major destabilizing impact.

QUESTION 2

Which roles do countries occupy in international trade, where are the centres of use and demand, and where are the locations of international supply of resources? What factors determine this distribution?

As far as the distribution of suppliers and users in the world economy is concerned, the last century witnessed high-income industrial countries importing a large amount of resources, mainly from countries with low income levels, and exporting a smaller (but more valuable) amount of processed goods to them and to one another. Since the turn of the century, however, relations between North and the South have become more symmetrical: the share of South-South trade has doubled in monetary terms and now amounts to almost one third of global trade; the share of North-North trade, on the other hand, has shrunk, while the North exports more to the South than ever before (Lee et al., 2013).[38]

The aforesaid differences in trade patterns between high-income (and high consumption) and lower-income countries become even more pronounced when one assesses the upstream resource requirements of trade rather than direct trade flows. Such trends signify an externalization of resource-intensive processes from high-income countries to developing and emerging economies, thereby prolonging the patterns of direct trade that prevailed in the 20th century. Indeed, the changes in direct trade patterns observed in recent years (namely, of some industrialized countries again exporting raw materials, and emerging countries such as China switching to becoming major importers) are not so pronounced, if upstream material requirements are considered.

Although it is apparent that income remains relevant in shaping the distribution of international trade, this is giving way to another variable: population density. Densely populated countries increasingly appear as net importers on world markets, while sparsely populated countries are supplying materials. This is the case for trade in biomass and metals, though not for the trade in fossil fuels.

38. Lee, B., Preston, F., Kooroshy, J., Bailey, R., Lahn, G., 2013. Resources Futures. Royal Institute of International Affairs, London, UK.

QUESTION 3

What are the upstream resource requirements of international trade?

In an examination of international trade from an environmental/resource efficiency standpoint, the information gained on upstream resource requirements (as opposed to physical flows) can provide valuable insights. These requirements refer to additional resources used in the country of origin for producing traded goods, but ''left behind'' as wastes and emissions. Also known as ''resources embodied in trade'', they can serve as proxies for environmental impacts of trade.

Upstream resource requirements have been calculated for materials, energy, water and land. Methods used to estimate upstream material requirements include environmentally extended input-output models (IO), life-cycle assessments (LCA), as well as ''hybrid'' LCA-IO approaches. Energy requirements can be expressed either as energy resources used (in primary energy) or as CO2 emissions caused by the use of energy resources. For upstream water requirements, the term "virtual water accounts" is commonly used. Upstream land requirements have been addressed as "global hectares" in the foot-printing tradition as well as – indirectly – by accounting for so-called Human Appropriation of Net Primary Production (HANPP).

Despite intensive research efforts in the past decade, it is difficult to estimate the burden of upstream requirements of traded goods. Different approaches arrive at widely varying results that do not allow for easy comparisons and the drawing of solid results. Depending on resource and estimation method, upstream resource requirements range between 40 per cent and, in some cases, 400 per cent of traded materials.

If one attempts to draw some general conclusions, research results seem to confirm that the upstream resource requirements of international trade have been rising over-proportionally during recent decades, and at a faster rate than global material extraction. As mentioned earlier, analyses of upstream requirements also accentuate inequalities in resource use between high-income and low-income countries: high-income countries have in the order of 50 to 100 per cent larger positive trade balances, as measured in raw materials rather than by direct trade, while for low-income countries the opposite is true.

QUESTION 4

Does international trade improve or worsen the global efficiency of resource use?

A central question addressed in the report relates to the implications of trade for the global efficiency of resource use. This is an increasingly important issue in a global situation of tight resource supplies, escalating demand and increasing competition for access.

International trade plays a vital role in overcoming mismatches between supply and demand for natural resources. In principle, trade allows allocation of extraction activities to regions where resources are available in high quality and where extraction activity is least resource-intensive. This results in lower costs (in economic terms, but possibly also in social and environmental terms) and could support rising resource efficiency at a global level.

The impact of trade on economic efficiency is more apparent. With trade seen as allocating resources from countries where they are available and extracted at a lower monetary cost to countries where extraction costs would be higher, it arguably improves global economic efficiency.

The consequences of trade for environmental/resource efficiency, however, are much more multifaceted and harder to evaluate. In theory, if trade were structured in a way that enabled resources to be extracted and commodities produced where they exerted the least environmental pressure, it would be resource-efficient. As far as external costs are internalised, international trade will bring about resource transfers in which the environmental burdens and losses associated with resource extraction and use are taken into account. Whilst environmental considerations may be included to some extent in extraction costs, the latter are more likely to be determined by other factors (such as wage levels, technological know-how, energy costs, transport infrastructure and national regulations). Hence, environmental and resource issues would largely remain as external costs, and greater resource efficiency be far from guaranteed.

In assessing whether international trade improves global resource efficiency, a closer look at the upstream resource requirements of traded commodities is instructive. One could argue that if trade enhanced environmental efficiency, then the increase of international trade could be expected to gradually improve the quantitative relation between traded products and the upstream resource requirements for producing them. If, on the contrary, upstream requirements increase faster than the volume of traded products, other mechanisms dominate. In general, the evidence points to rising upstream resource requirements (in terms of materials, energy, water and land) of traded goods. This can be attributed to a number of factors. including:

- an increasing share of higher-processed goods in total trade
- higher trade activities in general
- poorer ore grades for metals and minerals, and declining EROEI for fossil fuels
- increasing consumption of fossil energy carriers for fuelling transport
- population growth and increasing food demand in arid regions

Hence, these factors may well outweigh a potentially more resource-efficient allocation of extraction and production processes in world trade.

On the whole, the answer to the question of whether trade leads to greater global environmental efficiency remains indeterminate. Given the multiple current research efforts, aimed at improving analysis of upstream requirements, more conclusive answers may emerge.

However, it does appear that trade leads to a redistribution of environmental burdens towards resource-extracting and -producing countries. By depleting their natural resources, exporting countries have to deal with wastes and emissions from primary processing, and may not be gaining high economic revenue. For instance, the export of biomass from regions such as Latin America, North America and areas in Sub-Saharan Africa has led to loss of forest cover, land degradation and other negative ecosystem changes.

On a more positive note, there is a role for policy to partly mitigate such adverse environmental impacts. An illustrative example relates to the up to 90 per cent reduction in harmful sulfuret dioxide (SO2) emissions from the mining of platinum, owing to favourable advancements in process technologies, voluntary initiatives and regulatory frameworks. In addition, other policy initiatives such as the phasing out of fossil fuel subsidies, could have a catalytic role in discouraging extraction and consumption of fossil fuels, reducing CO2 emissions and averting climate change, as well as spearheading the urgently needed transition towards renewable energy sources and a green economy pathway.

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The availability and accessibility of natural resources is essential for human well-being. Natural resources are unevenly distributed, and the limits to their availability in many parts of the world are becoming increasingly visible. International trade has played an important role in delivering resources from centres of supply to centres of demand.

In the past few decades global efforts have been channelled to enforce sustainable management strategies for natural resources, increase resource and environmental efficiency and thus, overall human well-being. In such a context, what role does international trade play in increasing resource efficiency, reducing environmental impact and promoting equitable and inclusive growth?

Through a comprehensive review of updated data and existing literature, the latest assessment from the International Resource Panel International Trade in Resources: A Biophysical Assessment examines the rapid growth and pattern changes of resource trade and analyzes the upstream resource requirements of traded commodities including materials, land, energy and water. The report seeks to shed light on:

- the dramatic rise in international trade in recent decades, with over a six-fold increase in value and more than doubling of its volume between 1980 and 2010;
- the indirect resources associated with trade, i.e. resources used in the production process but not physically included in the traded goods;
- the increasing dependency on world markets to supply the demand for resources, across all material categories with fossil fuels and metals accounting for the highest share;
- the changes that patterns of trade dependence has experienced with high-income countries remaining main recipients of resources via trade and emerging economies, such as China, becoming major importers; and
- the rapid increase in upstream requirements of traded commodities -in terms of materials, water, land and energy - the estimates of which range widely from 40 up to 400 per cent of traded materials.

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Job Number: DTI/1872/PA

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