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How does the development of the financial industry advance renewable energy? A panel regression study of 198 countries over three decades.

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Abstract
We investigate how the development of the financial industry connects with renewable energy. We analyze 198 countries over three decades in various model settings (fixed effects, random effects, dynamic panel). We use a wide range of proxies for the development of the financial industry and establish that in general this development has a positive impact on renewable energy capacity. Especially, the relative size of the commercial banking industry as well as of private credit and the size of the financial industry play a crucial role in advancing renewable energy investments.

JEL: C33, E22, G10, Q42

Keywords: Renewable energy; Financial industry; Panel data analysis.

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1 Introduction

The International Energy Agency (IEA, 2011) estimates that the global investment in energy supply infrastructure will require $ 38 trillion over the period 2011-2035 (on average $ 1.5 trillion per year). Oil and gas account for half of this amount and the power sector will claim most of the remainder, especially for transmission and distribution networks. Most of the medium-run growth in energy demand is forecast to come from the developing world, which consumes more energy than the developed world since 2007 and is expected to do so in the future (Wolfram et al., 2012).The IEA also observes that the age of fossil fuels is far from over but that their dominance declines. It expects that higher fossil-fuel prices and increasing concerns about energy security and climate change will stimulate the development of renewable energy for electricity production. In addition, nation- and worldwide policies, like the Kyoto Protocol and the European Union´s Emissions Trading Scheme, are implemented in order to protect the environment (Chin-Ping et al., 2009).

The transition to more renewable and sustainable energy sources requires huge investments. Even though investments in renewable energy for electricity, biofuel and heating have increased, renewable energy still accounts only for a small part of the total energy supply (almost 10% of the global primary energy needs; IEA, 2011). Active business and investor support to focus on climate change and clean technology continues to grow (Fulton et al., 2010). Investments in renewable energy reached $ 162 billion in 2009, almost four times as large as the 2004 figure and equivalent to about 37 percent of the investments made by the oil and gas industry in that year (UNEP, 2010). In 2009, there was a remarkable shift in the focus of the renewable energy industry from Europe and North America to Asia: China became the biggest single contributor to renewable energy investment. Europe maintained its position as the region with the largest share of financial investment in clean energy, but it was challenged hard for the first place by Asia. The role of renewables in developing countries is growing; especially in China, Brazil and India, who attract the majority of investments of the developing countries (Nguyen-Van, 2010).

The European Union and China take a leading role with the rapidly increasing investment in renewable energy (IEA, 2011; UNEP, 2010). They have an investment base that is comfortable with financing renewable energy projects, especially when it comes to financing in advance stages of the development, like public market investment and asset finance. Renewable energy has greater upfront capital costs per gigawatt than fossil fuel generation, especially when embedded fossil fuel subsidies and the cost of carbon pollution and other external effects remain unpriced (IEA, 2011). Renewable energy technologies must first prove themselves commercially before they can make a difference. While venture capital and corporate R&D departments are able to finance initial pilot-scale projects, they do not have the financial resources to deploy large-scale projects. Major financial institutions can routinely finance these projects, yet because of their conservatism only do so if the used technologies are proven (Mathews et al., 2010). As a result, many renewable and sustainable energy innovations do not take-off.

In the power sector, which has been dominated by the public sector in the last few decades, traditional public sector financing methods may not be adequate to meet future demand for energy services, especially for developing and emerging economies but also for industrialized countries due to their increasing public debt. The key for starting renewable energy projects therefore is the access to long-term finance, since history shows that the financing of major infrastructure projects is enhanced by private debt financing (Mathews et al., 2010). Yet private participation in public services is difficult, especially for low-income and developing countries, since these countries lack proper financial instruments to mitigate risks related to infrastructure projects and they are missing or have low sovereign credit ratings (Ba et al., 2010). In countries with well-developed financial markets, banks are better able to offload risks (Beck et al., 2007), which can help firms raise finance for their projects.

The purpose of this paper is to analyze whether and how the financial industry might have an impact on the development of renewable energy. In order to answer this question, the influence of several indicators of financial sector development will be estimated. To this extent, we rely on an unbalanced panel of 198 countries over the period 1980-2008. Our dataset includes financial industry indicators, measures of renewable energy development and several variables that control for other important factors related to renewable energy development, like economic, energy and policy indicators. We employ panel data techniques to investigate the impact of financial development on renewable energy development.

The remainder of this paper is organized as follows: Section 2 gives a brief overview of the literature on renewable energy and provides a background for our analysis. Section 3 introduces the methodology and the data. The results are presented and discussed in section 4. Section 5 concludes the analysis.

2 Background

The prospect of renewable energy as a solution for some of the main energy challenges has led to a vast amount of literature. Some studies link the development of renewable energy to economic growth (Menegaki, 2011), specified for energy prices (Chang et al., 20009), or for energy consumption (Apergis and Payne, 2012). Others focus on renewable energy development for a specific group of countries. For example, Sadorsky (2009) looks into the G7 countries. Marques and Fuinhas (2011) focus on a set of 24 European countries in order to find the drivers behind renewable energy. Menegaki (2011) investigates economic growth in connection with renewable energy for 27 European countries. Eyraud et al. (2011) investigate 35 advanced and emerging countries in the last decade. In addition, several studies focus on one country in particular, like Chaurey et al. (2003) on India and Kann (2009) on Australia.

From this literature, it appears that the main barriers include high costs of particular technologies in the absence of subsidies, relatively limited research and development, lack of skilled labor and policymaking capacity, skepticism about the viability of renewables, and inadequate investments in networks. In the short run, the limited annual operating hours and uncertainty about the costs appear to bind the potential electricity contribution of renewable sources (Bosetti et al., 2009). Furthermore, Apergis et al. (2010) find that renewable energy does not contribute to reductions in CO_2 emissions in the short run. More time and capacity is needed for these sources to be able to significantly contribute to the decarbonization of the power sector. The intermittency of the renewable energy sources suggests that there will be a significant need for demand management, storage facilities or reserve production capacity, which will affect the investment costs of a renewable energy system (Trainer, 2010). Alagappan et al. (2011) find that renewable energy development has been more successful in markets that use a feed-in-tariff. A feed-in system is a policy mechanism that ensures a price above the market price for the renewable energy producer. If the tariff is set too low it will not have a significant effect, while a tariff that is set too high will trigger investment at increasingly disproportionate costs to the consumer (Mitchell et al., 2006). The design of feed-in tariffs differs per country; some apply only to specific technologies or maximum capacity, but they are usually related to the cost of generation (REN21, 2005; Kleßmann (2012). Although feed-in-tariffs may not seem very efficient in the short-term, they appear to provide long-term stability, incentives and resources for innovation leading to long-term efficiency improvements (Mitchell et al., 2006; Hirschhausen, 2014).

The share of renewables in the global primary energy needs is higher in electricity generation, accounting for almost 20 percent of the total, of which the majority is from hydropower plants (16 percent) (IEA, 2011). In existing renewable power (absolute) capacity at the end of 2009, China leads the ranks, followed by the United States and Germany. Total renewable power capacity reached 1,230 GW in 2009, of which 980 GW came from hydropower

(REN21, 2010) and which comprises about one-quarter of global generating capacity (UNEP, 2010). This pattern is not the same in all countries. Sadorsky (2009) finds that real GDP growth and CO2 emissions drive renewable energy consumption in the G7 countries. In contrast, Menegaki (2011) finds only a very weak relationship between economic growth and renewable energy consumption in Europe. Brunnschweiler (2010) finds that major oil and gas producing developing countries generally use less renewable energy sources for electricity generation, particularly in case of non-hydropower renewables. Marques and Fuinhas (2011) confirm this finding for Europe. Eyraud et al. (2011) find that 'green' investment is stimulated by economic growth, a sound financial system conducive to low interest rates, and high fuel prices.

Financial industry investments by the developing world in renewable energy have risen from $3.2 billion in 2004 to $50.7 billion in 2009 (UNEP, 2010). As such, their share has increased from less than 20% to more than 40% of total renewable energy investments. Therefore, the renewable energy industry and the financial industry seem to depend upon each other, although this relationship is not very smooth (Wohlgemuth and Painuly, 2002). Eyraud et al. (2011) and Brunnschweiler (2010) find that financial industry development in non-OECD countries has a robust and significant positive effect on the amount of renewable energy produced, particularly for non-hydropower renewables. Public investments may be helpful for the development of the technologies and the supply of renewable energy, but a combination of both public and private finance seems to be necessary to meet the ambitious emission reduction objectives (Aguilar and Cai, 2010) and to integrate renewable sources into the energy system (Wohlgemuth and Painuly, 2002). Since renewable energy technologies are characterized by high upfront costs (Szabó and Jäger-Waldau, 2008), they are largely dependent on external finance. Czarnitski et al. (2010) argue that firms have to rely on internal funds for financing their research, even more compared to their development activities, which could be a problem for renewable companies given the fact that research and development in this sector is limited (Bosetti et al., 2009). This would increase the relative costs of these technologies even more.

Only few studies specifically focus on the relationship between financial industry and renewable energy industry development. Brunnschweiler (2010) focuses on 119 developing countries in the period 1980-2006. Marques and Fuinhas (2011) investigate 24 European countries during 1990-2006. We try to complement this literature by encompassing 198 countries and study the period 1980-2008. We combine developed and developing countries, in order to make inferences on renewable energy growth and the corresponding role of the financial industry. We use variables on financial development, economic development, renewable energy and conventional energy that are identified in the work of, among others, Sadorsky (2009), Brunnschweiler (2010), Eyraud et al. (2011), Marques and Fuinhas (2011), and Menegaki (2011). We use a methodology that is highly similar to the one employed in Marques and Fuinhas (2011). Apart from including the price of fossil fuels as control variables (as done by Sadorsky, 2009, Brunnschweiler, 2010, and Marques and Fuinhas (2011), we also include fossil fuel reserves. Furthermore, we include policy variables since many studies discuss the effectiveness of renewable energy promotion policies (Eyraud et al., 2011; Frondel et al., 2010; Gross et al., 2010; Kleßmann, 2012). In the next section, we introduce our models and explain the methodology and data used.

3 Model, Methodology and Data

3.1 Model and methodology

We use a multivariate panel data approach, which makes it possible to study information across both time and space. A panel of data consists of a group of cross-sectional units, e.g. people, households, firms or countries, who are observed over time. It refers to any dataset with repeated observations over time for the same cross-sectional units. In this study, we have an unbalanced panel of 198 countries over 29 years, which means that some cross-sectional elements have fewer observations or have observations at different times than others. Several techniques are available to model such a panel. In this study, the fixed effects model and the random effects model will be used followed by a dynamic panel data approach.

3.1.1 Fixed-effects model

The fixed effects model is a method for pooling time-series and cross-sectional data. It is an appropriate specification if one focuses on a specific set of countries. The fixed effects model assumes that all individual differences are captured by the intercept. It is flexible since it allows each parameter to change for each individual in each time period. The disturbance term is decomposed into an individual specific effect and a remaining disturbance term that varies over time and individuals (here: countries). Note however that the fixed effects model cannot include variables that are constant for each cross-section over time. In this study, the following fixed effects model will be estimated, following Marques and Fuinhas (2011):

$$\gamma_{it} = \alpha + \beta_1 F_{it} + \beta_2 E_{it} + \beta_3 X_{it} + u_{it} \qquad (1)$$

where γ_{it} is the dependent (renewable energy) variable in country i at time t, α is the intercept term, F_{it} is the financial industry indicator, E_{it} is a vector of energy related variables and X_{it} is a vector of control variables. The disturbance term u_{it} is decomposed into an individual specific effect μ_{it} and the remaining disturbance υ_{it}, according to $u_{it} = \mu_{it} + \upsilon_{it}$. Since signs of first order autocorrelation are detected by very low values of the Durbin-Watson statistic, a fixed effects panel model with a first order autoregressive disturbance term will be estimated, in order to remove serially correlated errors. In this case, the error term will be decomposed as follows: $u_{it} = \rho\mu_{i,t-1} + \varepsilon_{it}$. This autoregressive error model captures autocorrelation in the errors and models the dynamic effects of the error term.

3.1.2 Random-effects model

The random effects model is appropriate when N individuals are randomly drawn from a large population. In this model, also known as the error components model, it is also assumed that individual differences are captured by the intercept, but the individual differences are treated randomly rather than fixed since the individuals in the sample are randomly selected. The random effects model has a random variable ε_i that varies cross-sectional but is constant over time. In this study, the following random effects model will be estimated:

$$\gamma_{it} = \alpha + \beta_1 F_{it} + \beta_2 E_{it} + \beta_3 X_{it} + \omega_{it} \qquad (2)$$

where γ_{it} is the dependent renewable energy variable in country *i* at time *t*, α is the global intercept term, F_{it} is the financial industry indicator, E_{it} is a vector of energy related variables and X_{it} is a vector of control variables. The composite error term ω_{it} consists of a cross sectional error term ε_i and an individual observation error term υ_{it}, according to $\omega_{it} = \varepsilon_i + \upsilon_{it}$.

It is not always clear whether fixed or random effects should be used. Explanatory variables that do not vary over time will not be removed with random effects, making it possible to specify their impact on γ_{it}. Moreover, since a random effects model has fewer parameters to estimate, which saves degrees of freedom, it should produce more efficient estimations. However, the random effects model is only valid when the composite error term ω_{it} is uncorrelated with the explanatory variables. The random effects model is a generalized least squares (GLS) estimation procedure, which can help a researcher to deal with heteroskedasticity or autocorrelation, and the fixed effects model is a least squares estimator, which requires a linear model.

Hausman (1978) proposes a misspecification test which makes it possible to compare random effects estimates with fixed effects estimates to see if significant differences occur. If there is no correlation between the individual differences υ_{it} and the explanatory variables, both estimators are consistent and should converge to the true parameter values in large samples. The random effects estimator is inconsistent if υ_{it} is correlated with any of the explanatory variables while the fixed effects estimator remains consistent. We use a five percent critical value in order to determine whether the null hypothesis of no correlation should be rejected, in which case the random effects model is inefficient and a fixed effects estimator should be used.

3.1.3 Dynamic panel model

Many economic relationships are dynamic in nature and are characterized by the presence of a lagged dependent variable among the regressors. In that case, a dynamic model is a useful tool to cope with autocorrelation and has several advantages. First, it will eliminate individual non-observable effects of countries. By using delayed values of the independent values as instruments, endogeneity between these variables will be handled. Finally, it deals with collinearity between variables and it allows to test whether the actual level of renewable energy development is related to previous levels (Marques and Fuinhas, 2011). Arellano and Bond (1991) suggest a linear dynamic panel model with a generalized method of moments (GMM) estimator. A GMM estimator is obtained by finding the element of the parameter space that sets linear combinations of the sample cross-sections as close to zero as possible (Hansen, 1982). When the least squares estimators are biased and inconsistent, the method of moments leads to an alternative estimation that will work in large samples. So, in order to test for the possibility of dynamic effects in the development of renewable energy capacity, a dynamic model will be specified, following Brunnschweiler (2010) and Marques and Fuinhas (2011):

$$\gamma_{it} = \alpha + \delta\gamma_{i,t-1} + \beta_1 F_{it} + \beta_2 E_{it} + \beta_3 X_{it} + u_{it} \qquad (3)$$

where γ_{it} is the dependent renewable energy variable in country *i* at time *t*, α is the intercept term, $\gamma_{i,t-1}$ is the level of renewable energy development in country *i* at time *t-1*, F_{it} is the financial industry development indicator, E_{it} is a vector of energy related variables and X_{it} is a vector of several control variables. The error component consists of an unobservable individual specific effect μ_{it} and a remainder disturbance term υ_{it}, according to $u_{it} = \mu_{it} + \upsilon_{it}$. Our models are linear, which indicates that they are linear in the parameters α and β but not necessarily in the variables.

In order to use these models the dependent variables will be transformed into their natural logarithms, which will lead to a log-linear model.

3.2 Data

The data we use to answer the research question combines two datasets. The first one is the New Database on Financial Development and Structure, from Beck et al. (2000), which was updated by the World Bank in November 2010. This database consists of indicators of financial development and financial structure across countries from 1960 up to 2009. The second database consists of renewable electricity capacity (or generation) data from the US Energy Information Administration (http://www.eia.gov/fapps/ipdbproject/iedindex3.cfm? tid=2&pid=29&aid=7&cid=regions&syid=2004&eyid=2008&unit=MK). It provides information about the total (renewable) electricity generation and capacity for all countries from 1980 until 2008. Furthermore, it provides information about reserves in coal, oil and natural gas and information about per capita carbon dioxide emissions from the consumption of energy and per capita total primary energy consumption. Following equations *(1), (2)* and *(3),* the variables used in this study can be divided in four groups. The first group consists of dependent variables consisting of estimators of renewable energy development. The second group consists of financial industry development variables. The third group consists of conventional energy related variables and the fourth group consists of a set of controls.

3.2.1 Renewable energy variables

There are several sources of renewable energy, of which hydropower is the leading source of electricity worldwide. However, it is sometimes argued that large hydropower projects should not be included among the renewable energy sources due to their negative externalities (Brunschweiler, 2009; Abbassi et al., 2011). Moreover, the majority of hydro projects considered in developing countries would not have been financed without some form of public sector support, like direct funding or support mechanisms provided by multilateral or bilateral organizations (Head, 2000). Therefore, we will also study renewable energy by excluding hydropower in some of the estimations. The sources of renewable energy that will be included are wind (onshore and offshore), biomass, geothermal, solar, tide and wave. This leads to the following dependent variables: *totreic* (total renewable electricity installed capacity), *totnhreic* (total non-hydroelectricity installed capacity) and *recshare* (the share of renewable capacity in total electricity installed capacity). Since capacity must be build first in order to generate energy with renewable sources, capacity is a more direct measure of total investments in this sector and therefore these variables (*totreic, totnhreic* and *recshare*) will be used for the main regressions.

3.2.2 Financial industry variables

The financial variables are based on Beck et al. (2001). They distinguish between three groups of financial institutions: central banks, which includes institutions that perform functions of the monetary authorities, deposit money banks, which according to the International Monetary Fund (IMF) comprise commercial banks and other financial institutions that accept and have liabilities in the form of transferable deposits, and other financial institutions, which is made up of other banklike institutions and nonbank financial institutions. This last group includes institutions that serve financial intermediaries while not incurring their liabilities usable as a means of payment (e.g. mutual funds, insurance companies, pension funds). In order to measure the relative importance of deposit money bank assets relative to central bank assets, we use deposit money over central bank assets (*dbacba*). In countries with a well-developed financial sector, banks provide more services and are better able to divest risks, and by doing so they can maintain more liquid balance sheets. When we assume that the commercial financial sector is more efficient in allocating credit than the public sector, *dbacba* should have a positive relationship with renewable energy development (see also Brunnschweiler, 2010).

Liquid liabilities to GDP (*llgdp*) equals currency plus demand and interest-bearing liabilities of banks and other financial intermediaries divided by GDP. Since this indicator includes the three groups of financial institutions, this is the broadest available indicator of financial intermediation. We assume that the size of the financial intermediary sector is positively correlated with the provision and quality of financial services and therefore it is expected that this indicator has a positive influence on renewable energy development. The ratios of central bank assets to GDP (*cbagdp*) and deposit money bank assets to GDP (*dbagdp*) measure the size of these sectors relative to GDP and reveal the importance of the financial services relative to the size of the economy. Public finance plays an important role, but the mobilization of private finance to help solve the threat of global warming seems at least as important (Mathews et al., 2010). To measure the activity of financial intermediaries other than the central bank in channeling funds to investors, e.g. credit issued to the private sector, the indicator private credit by deposit money banks and other financial institutions to GDP (*pcrdbofgdp*) is used. Private credit isolates credit issued to the private sector, as opposed to credit issued to governments and public enterprises. As higher levels of this indicator indicate higher levels of financial services, we expect that private credit has a positive impact on renewable energy development.

Concentration defines the ratio of the three largest banks' assets to the total banking-sector assets. A high ratio can indicate a lack of competitive pressure to attract savings and channel them efficiently to investors while a low ratio can be a sign of a highly fragmented market which can be evidence of undercapitalized banks. Lastly, stock market capitalization divided by GDP (*stmktcap*), which equals the value of listed shares divided by GDP, gives an indication of the relative size of the stock market. Demirgüç-Kunt and Maksimovic (1999) argue that an active stock market is better in directing long-term credits to firms, which is needed for investments in renewable energy infrastructure. Therefore, we investigate the impact of stock markets on renewable energy too and will include stock market size in some of the estimations.

3.2.3 Conventional energy variables

For conventional (fossil) resources, we include the reserves of crude oil (*copr*), natural gas (*prng*) and recoverable coal (*reccres*) in the analysis (fossil-fuel reserves are transformed to kilowatt-hours). When looking at the Gulf countries, which mainly use domestic fossil fuels for their domestic energy supply, it seems that despite the favorable conditions for solar energy, renewable energy applications are underdeveloped (Reiche, 2010). Therefore, we will analyze the effect of the amount of these fossil fuel reserves on renewable energy. The prices of the fossil fuels (*oilprice, gasprice and coalprice*) are also included, since a higher price level may be expected to stimulate investment in alternative resources (see the BP Statistical Review of World Energy 2010; www.bp.com/statisticalreview). Oil is considered to be the most likely substitute for renewable energy (Sadorsky, 2009) and is therefore included in the main regressions. Lastly, following Marques and Fuinhas (2011), carbon dioxide emissions per capita ($pcCO_2$) and energy consumption per capita (*pcenergy*) is included. We expect that higher emissions of CO_2 will have a positive effect on renewable energy development. Besides, Marquis and Fuinhas (2011) show that per capita energy consumption has a positive influence on renewable energy in European countries, and it is to be expected that more consumption will create pressure on the production of energy from renewable energy sources.

3.2.4 Control variables

In order to measure the effect of the development of the financial industry on the development of renewable energy, several control variables are included. We account for GDP per capita (*gdppop*), since it is obvious that richer and more developed countries require more energy (Brunnschweiler, 2010), and therefore more investments in renewable energy. The ratio of FDI to GDP (*fdigdp)* is included in order to account for non-domestic investment. Especially in the case of low-income countries we expect that this measure has a positive impact on renewable energy development.

Furthermore, it is interesting to investigate policies that aim at stimulating renewable energy generation: More than 100 countries have some renewable energy policy target and/or promotion policy in 2010 (REN21, 2005, 2010; Menanteau et al., 2003). Since the limited time-span of the data this variable will be tested separately in order to use as much observations as possible. Policies included are: feed-in-tariff; renewable portfolio standard; capital subsidies and grants or rebates; investment or other tax credits; sales tax, energy tax, excise tax, or VAT reduction; tradable renewable energy certificates; energy production payments or tax credits; net metering; public investment, loans, or financing; public competitive bidding. We construct a dummy variable *pol*, which has a value of one for countries that include a feed-in-tariff or capital subsidies, grants or rebates. Since a feed-in-tariff and capital subsidies, grants or rebates are the most common promotion policies used, the dummy variable (*pol*) will be constructed for countries which enact such a policy, without giving any weight to a specific policy since this is beyond the scope of this research.

Several other variables are included as well. Van der Ploeg and Poelhekke (2009) assume that resource rich and landlocked economies have less developed financial systems than resource-poor countries. Therefore, a dummy for whether or not a country is landlocked is included. We look into the different World Bank income groups in order to make inferences related to the development of countries; the countries are divided into low income, lower middle income, upper middle income and high income groups.

The descriptive statistics of the variables is shown in Table 1. The data about renewable energy (our dependent variables) are available for almost all the years and countries, since the maximum number of observations is 5742 (198 countries and 29 years). Some of the dependent variables are highly skewed to the right, e.g. depart from normality. In order to make the larger values of variables less extreme, they are transformed into natural logarithms. The dependent variables all have a minimum of zero, and as it appears this observation occurs often within the series. The value of one is added to the observations in order to overcome the problem of losing data (Pinches and Mingo, 1973); subsequently they are transformed to their natural logarithm. The variables that have undergone this transformation are indicated with an asterisk (*) in Table 1.

Table 1 reveals that there is a wide variety in the dependents. Interesting is that hydropower is the leading source of renewable electricity worldwide. The descriptives also suggest that the majority of countries do not yet dispose of the necessary infrastructure for these types of renewables. This can be seen in the wide range between the minimum and maximum values. It is also interesting that for some countries, renewable energy sources account for most of their electricity generation (see *recshare*).

[Insert Table 1 about here]

Table 2 gives the correlations between the variables. As expected, there is a high correlation between the corresponding renewable capacity and generation variables, since generation is dependent on the available capacity. With a few exceptions, the financial variables are modestly but significantly correlated with each other. This confirms the need to use the measures separately, since each measure may capture different information regarding financial development. As can be seen, there is a modest correlation between the financial and dependent variables, where the highest correlation of 0.515 is between non-hydro renewable electricity generation (*nhreneg*) and private credit by deposit money banks and other financial institutions over GDP (*pcrdbofgdp*). The prices of the traditional energy sources also are highly correlated, therefore only one of them will be included as a control variable in order to avoid multicollinearity. Table 2 shows a high correlation coefficient between per capita CO_2 emissions (*pcCO2*) and per capita primary energy consumption (*pcenergy*), so these variables will be separated and included in different regression models. The other correlations between the independent variables are smaller and are not expected to pose serious problems.

[Insert Table 2 about here]

Since the financial variables measure slightly different aspects of the financial sector and since some of these variables are highly correlated, the financial variables are separated in the regression in order to avoid multicollinearity. As the financial sector is not expected to have an instantaneous effect on capacity and/or generation, the estimations are performed with one-year-lags for all the financial variables and the control variable GDP per capita. With the energy commodity prices there is substantial volatility. Because of a limited number of observations, *reccres* will not be included in the main regressions and the effects of policy will be analyzed separately.

4 Results

In this section, we report the results from the estimations of our models. We first go into the fixed and random effects models and then into the dynamic panel model estimations. Table 3 gives the estimation results of the regressions on renewable energy capacity on the basis of using equation *(1)* and *(2)*, according to the outcome of the Hausman statistic: If the statistic is lower than 0.05 the fixed effects model is implemented and if the statistic is 0.05 or higher the random effects model is implemented. The tests are executed for three measures of renewable energy development and for six indicators of the development of the financial industry. Since signs of serial correlation were detected by very low values of the Durbin-Watson statistic, GLS procedures were used in order to deal with autocorrelation. Since the random effects model is a GLS estimation procedure, only the regressions with a fixed effects model are adjusted with cross-section GLS weights. The tests are conducted using cross-section fixed or random effects. Since some of the variables change slowly over time, it is not possible to conduct the tests with period-fixed effects, as these variables are collinear with the period dummies which cause the estimation to fail.

[Insert Table 3 about here]

Table 3 shows several interesting results, with a noticeable difference in the outcomes of financial industry development regarding the dependent variables. The financial industry variables have a significant impact on total renewable electricity installed capacity (*totreic*; renewable capacity) and on the share of renewable electricity capacity in total electricity capacity (*recshare*; share of renewable capacity). However, the coefficients change signs for renewable capacity and the share of renewable capacity. As such, the financial industry has a positive impact on renewable capacity as such, but there is a negative impact on the share of renewable capacity. The latter suggests that the financial industry is supporting renewable energy investments but also is inclined to invest even more so in conventional capacity. The financial variables do not have a significant effect on total non-hydro renewable electricity installed capacity (*totnhreic*; non-hydro capacity), except in the case of private credit by deposit money banks and other institutions (*pcrdbofgdp*, hereafter: private credit).

Since we use a log-linear model, a one unit increase in commercial bank finance (*dbacba*) results in approximately 6.6 percent increase in renewable energy capacity. This suggests that the commercial financial sector plays a role in the development of renewable capacity and in doing so it appears to be more efficient than the public sector, consistent with the results of Brunnschweiler (2010). Since we study a longer period and more countries, our results make her findings more profound. The result for liquid liabilities over GDP also is consistent with Brunnschweiler (2010); it suggests that the relative size of the financial sector has a positive influence on renewable energy capacity. Private credit has an impact of 11.3 percent in case of renewable capacity and this is even higher in case of non-hydro capacity, where a one-unit increase in private credit leads to an increase of 21.6 percent in non-hydro capacity. This suggests that financial intermediaries, other than the central bank, channel funds to investors in renewable energy. With both capacity and non-hydro capacity, *concentration* has a negative sign, but this sign is not significant for non-hydro. This suggests that a more concentrated bank market is not well able to channel funds very efficiently to investors in renewable energy capacity.

When analyzing the estimations for the control variables, the following results are of particular interest. First of all, GDP per capita (*gdppop*) has a significant but very small positive effect on all of the renewable energy variables. This result is consistent with previous studies like Brunnschweiler (2010) and Sadorsky (2009). The effects of the reserves of oil (*copr*) and gas (*prng*) are mixed and less significant, especially in the case of oil. The results show a significant but very small positive effect of the amount of reserves of natural gas on the amount of renewable capacity. The oil price has a very small positive and significant effect on the amount of renewable capacity and non-hydro capacity, but it has a small significant and negative effect on the share of renewables in capacity. This is in line with the findings of Marquis and Fuinhas (2011) and Sadorsky (2009). The effect of per capita primary energy consumption (*pcenergy*) is positive but insignificant for capacity, except for a small positive coefficient for private credit. However, in case of non-hydro capacity and the share of capacity, almost all outcomes are significant and negative, although with a very small coefficient. This would suggest that more energy consumption does not create much pressure to use renewable sources. This contrasts with the results of Marquis and Fuinhas (2011) and could be due to the fact that we include different income groups in our regressions.

In order to measure the effect of the development of the financial industry along different groups of countries according to their development, the regressions are executed for the different country income groups according to the World Bank (not reported here for brevity sake but available upon request). For countries with a high per capita income, there is a significant effect of the commercial financial sector on renewable energy capacity. Elsewhere, it mainly is *cbagdp* that positively impacts on the share of renewable energy capacity. Furthermore, a developed financial market is well-suited to direct long-term finance to firms. The results indeed show a positive impact, especially for non-hydro capacity where a one unit increase leads to a 8.6 percent increase in capacity. We find that stock market capitalization has a more distinct effect for low income countries and lower middle income countries. This suggests that banks play a more prominent role in lower- and upper middle income countries in case of renewable development as compared to their role in conventional capacity. Furthermore, foreign direct investment does not have a positive effect. The price of fossil fuel has a positive and, in most equations, significant result on renewable energy, accounting for an approximately 0.3 till 3 percent increase in renewable capacity. This is in line with the findings of Eyraud et al. (2011).

The results of the effect of policy on renewable energy development, measured by the dummy *pol* which takes the value one for countries that enact feed-in-tariffs or capital subsidies, grants or rebates, are shown in Table 4. Since the Durbin-Watson statistic was well above one and GLS weights could not be included, the tests are conducted with standard fixed and random effects with a correction for standard errors that are robust to serial correlation. It is surprising to find that the policy variable has a significant negative effect on non-hydro renewable energy capacity. Since many of the renewable energy promoting policies focus on these technologies (Menanteau et al., 2003), it was expected that the results would show positive signs. However, elsewhere in the literature, it shows too that renewable energy policies do not always have the intended effect. For example, Kleßmann (2012) finds a very limited net positive effect and in many cases even a negative impact of renewable energy policies on the creation of renewable energy capacity.

As to the development of renewable energy, almost all financial industry variables show a significant effect, with the same sign for all three dependent renewable energy development variables. Especially private credit shows a significant positive effect, just like central bank assets divided by GDP (*cbagdp*) and deposit money bank assets divided by GDP (*dbagdp*), indicating that both public and private financial services play an important role in renewable energy development. *Dbacba* shows a significant negative sign, which indicates that commercial banking does not play a stimulating role when controlling for policies. Although this contrasts with the findings of Brunnschweiler (2010), the results are very reasonable since the policies included in this study are financial incentives for renewable technologies, which make the pressure to look for commercial funds less pressing. Of particular interest in this table is the inclusion of per capita CO_2 emissions (*pcco2*). Table 4 shows mixed results here. In general, there appears to be a neutral or even negative impact on renewable energy development, in line with Marques and Fuinhas (2011), Menegaki (2011), and Sadorsky (2009), who investigate high income countries.

[Insert Table 4 about here]

Since signs of autocorrelation were detected and since we assume that renewable energy development has a dynamic nature, a dynamic panel approach is used to analyze the data too. The model is given by equation *(3)*. We use unbalanced panel data and therefore the two-step GMM estimator is applied, which is the optimal choice amongst the estimators. It can be obtained by stacking the equations for all periods and countries (Arellano and Bond, 1991). We use a Sargan test to check the results, and the outcomes of this test show that the restrictions created by using instruments are valid indeed. However, since it was not possible to create valid restrictions for the dependent variable non-hydro capacity (*totnhreic*), even when some of the control variables were left out of the equation, this variable is omitted from the estimation results. It was also not possible to control for landlocked countries as this characteristic does not change over time.

Table 5 presents the dynamic panel estimation results of equation (3). The highly significant lagged dependent variables suggest that our dynamic approach is justified. The results also show that all financial industry variables have a significant positive effect on renewable energy capacity and a significant negative effect on the share of renewable capacity, except for *dbacba*, which is positive for both dependent variables, consistent with Brunnschweiler (2010). Thus, we establish for a large number of countries over a period of three decades that the development of the financial industry, measured as the size and share of commercial banks (*dbacba* and *dbagdp*), the financial sector (*llgdp*), and private credit (*pcrdbofgdp*), has a positive influence on renewable energy capacity, varying from 1.1-2.6 percent per unit increase in the financial indicator. GDP per capita again has a significant positive effect, although very small, on both capacity and the share of capacity, in all but one of the equations. The reserves of fossil fuels have a limited but significant impact; Countries with large fossil fuel reserves have less renewable energy capacity. As expected, the price of oil also has a (small) positive effect on capacity but a negative effect on the share of renewable capacity. This suggests that higher oil prices stimulate the investment in alternative sources but do not induce the growth of renewable electricity capacity in overall electricity capacity. This is consistent with our results in Table 3 and with Sadorsky (2009), who arrived at a similar result for the G7 countries. Finally, energy consumption per capita has a negative but very small significant effect on both measures of renewable energy, in contrast to Marques and Fuinhas (2011). This implies that more energy consumption does not create enough awareness to switch to renewable energy sources, and we find no evidence of a Kuznets effect.

[Insert Table 5 about here]

5 Conclusion

We analyze the link between the development of the financial industry and the development of renewable energy. We use an unbalanced panel of 198 countries for the period 1980-2008 and use different estimation methods. As such, we extend the existing literature (esp.

Marques and Fuinhas, 2011; Brunnschweiler, 2010) and are able to make several earlier results of the impact of financial sector development on renewable energy development more profound (Eyraud et al., 2011; Marques and Fuinhas, 2011; Menegaki, 2011; Ba et al., 2010; Brunnschweiler, 2010; Mathews et al., 2010; Sadorsky, 2009). Energy consumption still relies for a large part on polluting and depleting fossil fuels but renewable sources are gaining ground. The renewable energy infrastructure has to be build first after which it can contribute to energy generation. Renewables usually require huge up-front investments and face high start-up costs. Since both public and private finance are needed to make the transition to renewable energy, this study analyzes the width and depth of the finance industry in this process. For this analysis, fixed effects and random effects panel techniques were used, as well as a dynamic panel approach which makes it able to investigate the development of renewable energy as a dynamic process.

Our findings contribute to the literature as we can now extend previous findings about economic development, renewable energy, conventional resources, financial structure, CO_2 emissions, and renewable energy policy (Eyraud et al., 2011; Marques and Fuinhas, 2011; Menegaki, 2011; Brunnschweiler, 2010; Sadorsky, 2009), to a much larger group of countries and for a more prolonged period of time while using basically the same methodologies. To be more specific, we find that the development of the financial industry, in the form of the size and share of commercial banks, the financial sector as a whole, and private credit, has a positive impact on overall renewable energy capacity. Thus, the financial industry does indeed stimulate the growth of renewable energy. Energy is an important sector and the large infrastructure projects related to the sector are capital-intensive. Since the renewable energy technologies face high start-up costs, they rely on external finance in order to lift their projects off the ground. Investments in renewable energy in 2009 were almost four times as large as the 2004 figure, which indicates the fast growth in the level of investments. However, public support is growing in many countries, something this study also tries to capture. The results show that private credit and both public and private financial services still play a significant positive role in renewable energy development when taking policy into account. In general, policy itself does not seem to contribute noticeably to the development of renewable energy.

Furthermore, we find that the development of the financial industry has a negative impact on the share of renewable electricity capacity in total capacity, which suggests that the financial industry still is more inclined to invest in conventional capacity. Another explanation could be that many renewable projects are decentralized and their capacity is self-generating, like solar panels on rooftops and micro combined heat and power generation. Due to this decentralization, it could be that the fruits from the self-generating capacity is not included in the national statistics regarding energy production. Furthermore, higher per capita energy consumption does not create enough pressure in high-income countries to switch to renewable sources whereas it has a positive impact on renewable development in other country income groups. The CO_2 emissions per capita suggest that the current levels of greenhouse gas emissions and, with this, social pressure, appear to be insufficient to switch to renewable electricity generation.

A concern of our research is that self-generation appears to be covered quite differently among the countries in our study, which may have an impact on our findings. In addition, the quality of the databases is subject to huge differences among our group of countries. Another weakness is that we cannot provide consistent information about types of (renewable) energy policies for the countries under review and can in this respect only focus on a relatively small part of the sample. In this respect, our conclusion can only be of a preliminary nature.

In all, we are able to show that the advancement of renewable energy is a complex process in which one has to account for a wide range of factors. We establish that the financial industry is one of the factors involved. But there is no blueprint for the transition from a fossil-based economy to an economy that is fueled by renewable resources. In particular, persistency and path dependency seem to play a role, in tandem with financial and economic development. At the same time, global market developments do have their impact too.

References

Abbasi, T., Premalatha, M., Abbasi, S.A., 2011. The return to renewables: Will it help in global warming control? Renewable and Sustainable Energy Reviews, 15, 891-894.

Aguilar, F.X, Cai, Z., 2010. Exploratory analysis of prospects for renewable energy private investment in the U.S., Energy Economics, 32, 1245-1252.

Alagappan, L., Orans, R., Woo, C.K., 2011. What drives renewable energy development?, Energy Policy, 39, 5099-5104.

Amel, D., Barnes, C., Panetta, F., Salleo, C., 2004. Consolidation and efficiency in the financial sector: A review of the international evidence, Journal of Banking and Finance, 28, 2493-2519.

Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y., 2010. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth, Ecological Economics, 69, 2255-2260.

Apergis, N. Payne, J.E., 2012. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model, Energy Economics, 34, 733-738.

Arellano, M., Bond, S., 1991. Some test of specification for panel data: Monte Carlo evidence and an application to employment equations, Review of Economic Studies, 58, 277-297.

Ba, L., Gasmi, F., Um, P.N., 2010. Is the Level of Financial Sector Development a Key Determinant of Private Investment in the Power Sector? World Bank Policy Research Working Paper 5373, 2010.

Beck, T., Demirgüç-Kunt, A., Levine, R., 2000. A new database on financial development and structure, World Bank Economic Review, 14, 597-605.

Beck, T., Demirgüç-Kunt, A., Levine, R., 2001. The financial structure database, in Demirgüç-Kunt, A. and R. Levine, Financial Structure and Economic Growth: a Cross-Country Comparison of Banks, Markets, and Development, MIT Press, Cambridge, Mass.

Beck, T., Demirgüç-Kunt, A., Martinez Peria, S., 2007. Reaching out: Access to and use of banking services across countries, Journal of Financial Economics, 85, 234-266.

Bosetti, V., Carraro, C., Massetti, E., Sgobbi, A., Tavoni, M., 2009. Optimal energy investment and R&D strategies to stabilize atmospheric greenhouse gas concentrations, Resource and Energy Economics, 31, 123-137.

Brunnschweiler, C.N., 2010. Finance for renewable energy: an empirical analysis of developing and transition economies, Environment and Development Economics, 15, 241-274.

Chang, T.H., Huang, C.M., Lee, M.C., 2009. Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from OECD countries, Energy Policy, 37, 5796-5802.

Chaurey, A., Gueye, M.K., Babu, N.Y.D., 2003. Financing renewable energy in India: A review of mechanisms in wind and solar applications, International Review for Environmental Strategies, 249-263.

Chin-Ping, C., Goldberg, L.R., Owyong, D.T., Shepard, P., Stoyanov, T., 2009. Is there a green factor? Journal of Portfolio Management, 35, 34-40.

Czarnitzki, D., Hottenrott, H., Thorwarth, S., 2010. Industrial research versus development investment: the implications of financial constraints, Cambridge Journal of Economics, 35, 527-544.

Demirgüç-Kunt, A., Maksimovic, V., 1999. Institutions, financial markets, and firm debt maturity, Journal of Financial Economics, 54, 295-336.

Eyraud, L., Wane, A., Zhang, C., Clements, B., 2011. Who's Going Green and Why? Trends and Determinants of Green Investment, IMF Working Paper 11/296, International Monetary Fund, Washington D.C.

Frondel, M., Ritter, N., Schmidt, C.M., Vance, C., 2010. Economic impacts from the promotion of renewable energy technologies: the German experience, Energy Policy, 38, 4048-4056.

Fulton, M., Kahn, B.M., Mellquist, N., Soong, E., Baker, J., Cotter, L., 2010. The Green Economy: The Race is On, Deutsche Bank Climate Change Advisors.

Gross, R., Blyth, W., Heptonstall, P., 2010. Risk, revenues and investment in electricity generation: why policy needs to look beyond costs, Energy Economics, 32, 796-804.

Hansen, L.P., 1982. Large sample properties of generalized method of moments estimators, Econometrica, 50, 1029-1054.

Hausman, J.A., 1978. Specification tests in econometrics, Econometrics, 46, 1251-1271.

Head, C., 2000. Financing of Private Hydropower Projects, World Bank Discussion Paper 420.

Hirschhausen, C. von (2014) The German " Energiewende" – An introduction. Economics of Energy & Environmental Policy, 3 (2), 1-12.

IEA (International Energy Agency), 2011. World Energy Outlook 2011, OECD/IEA, Paris.

Kann, S., 2009. Overcoming barriers to wind project finance in Australia, Energy Policy, 37, 3139-3148.

Kleßmann, C., 2012. Increasing the Effectiveness and Efficiency of Renewable Energy Support Policies in the European Union. PhD Thesis, Utrecht University.

Marques, A.C., Fuinhas, J.A., 2011. Drivers promoting renewable energy: A dynamic panel approach, Renewable and Sustainable Energy Reviews, 15, 1601-1608.

Mathews, J.A., Kidney, S., Mallon, K., Hughes, M., 2010. Mobilizing private finance to drive an energy industrial revolution, Energy Policy, 38, 3263-3265.

Menanteau, P., Finon, D., Lamy, M., 2003. Prices versus quantities: choosing policies for promoting the development of renewable energy, Energy Policy, 31, 799-812.

Menegaki, A.N., 2011. Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis, Energy Economics, 33, 257-263.

Mitchell, C., Bauknecht, D., Connor, P.M., 2006. Effectiveness through risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany, Energy Policy 34 (2006), 297-305.

Nguyen-Van, P., 2010. Energy consumption and income: A semiparametric panel data analysis, Energy Economics, 32, 557-563.

Pinches, G.E., Mingo, K.A., 1973. A multivariate analysis of industrial bond ratings, Journal of Finance, 28, 1-18.

Reiche, D., 2010. Renewable energy policies in the Gulf countries: A case study of the carbon-neutral ''Masdar City'' in Abu Dhabi, Energy Policy, 38, 378-382.

REN21, 2005. Renewables 2005 Global Status Report, Worldwatch Institute, Washington, D.C.

REN21, 2010. Renewables 2010 Global Status Report, Paris: REN21 Secretariat, Paris and Worldwatch Institute, Washington, D.C.

Sadorsky, P., 2009. Renewable energy consumption, CO2 emissions and oil prices in the G7 countries, Energy Economics, 31, 456-462.

Szabó, S., A. Jäger-Waldau, A., 2008. More competition: Threat or chance for financing renewable electricity? Energy Policy, 36, 1436-1447.

Trainer, T., 2010. Can renewables etc. solve the greenhouse problem? The negative case, Energy Policy, 38, 4107-4114.

UNEP, 2010. Global Trends in Sustainable Energy Investment 2010: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency, UNEP DTIE Paris.

Van der Ploeg, F., Poelhekke, S., 2009. Volatility and the natural resource curse, Oxford Economic Papers, 61, 727-760.

Wolfram C., Shelef, O., Gertler, P.J., 2012. How Will Energy Demand Develop in the Developing World? NBER Working Paper 17747, National Bureau of Economic Research, Cambridge, Mass.

Wohlgemuth, N., Painuly, J., 2002. Promoting private sector financing of commercial investments in renewable energy technologies, in: UN, Finance for sustainable development – testing new policy approaches, United Nations, New York, 319-334.

Appendix A
Description of the variables

Variable name	Variable	Description	Source
cn	Country	198 countries are included	New Database on Financial Development and Structure (2010)
year	Year	This study has a range of 29 years: 1980-2008	
dbacba	Deposit money bank assets / (deposit money bank assets + central bank assets)	Ratio of deposit money bank claims on domestic nonfinancial real sector to the sum of deposit money bank and central bank claims on domestic nonfinancial real sector	
llgdp	Liquid liabilities / GDP	Ratio of liquid liabilities to GDP	
cbagdp	Central bank assets / GDP	Claims on domestic real nonfinancial sector by the central bank to GDP	
dbagdp	Deposit money bank assets / GDP	Claims on domestic real nonfinancial sector by deposit money banks to GDP	
prcdbofgdp	Private credit by deposit money banks and other financial institutions / GDP	Private credit by deposit money banks and other financial institutions to GDP	
concentration	Bank concentration	Assets of the three largest banks in a country in relation to assets of all commercial banks	
stmktcap	Stock market capitalization / GDP	Value of listed shares to GDP	
totreic	Total renewable electricity capacity installed	Energy resources that are naturally replenishing but may be flow limited. They include: biomass, hydro, geothermal, solar, wind, ocean thermal, wav action, and tidal action.	Energy Information Administration (2011)
totnhreic	Total non-hydro renewable electricity	As totreic but without hydro resources	

	capacity installed		
toteic	Total electricity capacity installed	Maximum load of electric power by which generators, turbines, transformers, transmission circuits, stations or systems are rated.	
recshare	Share of renewable capacity in total electricity capacity installed	totreic over toteic	
toteg	Total net electricity generation	The process of producing electric energy (amount of electric energy produced) by transforming other types of energy	
reneg	Total renewable net electricity generation	See toteg and totreic above	
nhreneg	Total non-hydro renewable net electricity generation	See toteg, totnhreic and totreic above	
regshare	Share of renewable electricity generation in total electricity generation	reneg over toteg	
copr	Proven crude oil reserves	The estimated quantities of all liquids defined as crude oil that geological and engineering data demonstrate to be recoverable from known reservoirs under existing economic and operating conditions (transformed into kWh)	
prng	Proven reserves of natural gas	The estimated quantities of natural gas that analysis of geological and engineering data demonstrates to be recoverable from known reservoirs	

		under existing economic and operating conditions (transformed into kWh)	
reccress	Proven recoverable coal reserves	Estimated quantities of coal that analysis of geological and engineering data demonstrates to be recoverable from known reservoirs with the existing available technology (transformed into kWh)	
pop	Population levels (in 1,000, mid-year)	Annual average number of people present in a contry.	Groningen Growth and Development Centre / FAOSTAT
gdp	GDP	Gross domestic product at current prices (nominal GDP)	World Bank
lndlckd	Landlocked	Dummy, countries that are enclosed by land or closed seas = 1	CIA World Factbook
oilprice	Oil price	Oil spot cured price, West Texas Intermediate, in US dollar per barrel	BP Statistical Review of World Energy 2010
gasprice	Gas price	Average German import price in US dollar per million Btu	
coalprice	Coal price	Northwest European market price in US dollar per ton	
pcenergy	Total primary energy consumption per capita (in million Btu per person)	The use of energy as a source of heat or power or as a raw material input	Energy Information Administration (2011)
pcCO2	Per capita CO2 emission from the consumption of energy (metric tons of CO2 per capita)		
fdigdp	Net inflow of foreign direct investment (% GDP)	Net inflows of investment to acquire a management interest (>10% of voting stock) in an enterprise	World Bank

		in an economy other than where the investor is domiciled.	
pol	Policy	Dummy = 1 if a country enacts a feed-in-tariff, capital subsidies, grants or rebates	REN21
dlow	Low income country	Dummy, yes = 1	New Database on Financial Development and Structure (2010)
dlum	Lower middle income country	Dummy, yes = 1	
dupm	Upper middle income country	Dummy, yes = 1	
dhigh	High income country	Dummy, yes = 1	

Table 1: Descriptive statistics

This table shows the descriptive for 198 countries from 1980 to 2008. First the dependent variables are shown, covering renewable energy development indicators. Second, the financial variables which indicate financial sector development are shown. Finally, several control variables, which are related to the dependent variables, are included.

Variable	*#obs*	*Mean*	*Median*	*Max*	*Min*	*Sd*	*Skewness*
Dependent variables							
reneg*	5383	13.115	0.612	537.298	0.000	46.198	6.028
nhreneg*	5383	1.018	0.000	137.905	0.000	6.154	12.880
regshare	5353	0.321	0.168	2.831	0.000	0.351	0.817
totreic*	5404	3.509	0.189	186.820	0.000	11.697	6.306
totnhreic*	5404	0.266	0.000	39.435	0.000	1.697	12.431
recshare	5380	0.295	0.213	1.000	0.000	0.306	0.783
Financial variables							
dbacba	4291	0.789	0.871	1.264	0.017	0.224	-1.267
llgdp	3720	0.490	0.402	4.318	0.002	0.378	2.992
cbagdp	3570	0.086	0.046	2.650	0.000	0.132	6.500
dbagdp	3816	0.483	0.363	2.704	0.001	0.403	1.620
pcrdbofgdp	3814	0.424	0.290	2.698	0.001	0.384	1.543
concentration	2325	0.714	0.738	1.000	0.140	0.207	-0.378
stmltcap	1944	0.451	0.246	6.035	0.000	0.571	2.885
Energy variables							
copr	5072	5.322	0.000	266.810	0.000	23.827	7.097
prng	4980	21.323	0.000	1,700	0.000	108	11.275
reccres	358	12,277	397.000	249,994	0.000	37,999	4.323
coalprice	3762	50.768	41.250	147.670	28.790	27.327	2.414
oilprice	5742	31.460	25.930	100.060	14.390	19.198	2.039
gasprice	4950	3.825	2.890	11.560	1.880	2.239	2.037
pcenergy	5383	95.147	37.738	3.315.851	0.298	178.248	6.280
pcCO2	5359	5.738	2.216	170.013	0.006	10.949	6.207
Control variables							
gdppop	4914	6,405.80	1,811.43	111,639	66.958	10,552	3.050
pol	396	0.247	0	1	0	0.432	1.170
lndlckd	5742	0.197	0	1	0	0.398	1.524
fdigdp	4506	4.325	1.525	564.916	-82.892	19.508	19.128
dlow	5742	0.202	0	1	0	0.402	1.484
dlom	5742	0.258	0	1	0	0.437	1.109
dupm	5742	0.232	0	1	0	0.422	1.268
dhigh	5742	0.308	0	1	0	0.462	0.831

Table 2: Correlation matrix of relevant variables for the whole sample

This table shows the correlation coefficients between the relevant variables. Coefficients denoted with *** are significant at the 1% level, coefficients denoted with ** at a 5% level and coefficients denoted with * at a 10% level.

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Dependent variables																							
1	totreic	1																					
2	totnhreic	0.622***																					
3	rencapshar	0.292***	0.021																				
4	reneg	0.975***	0.568***	0.377***	1																		
5	nhreneg	0.697***	0.910***	0.023*	0.665***	1																	
6	regshare	0.215***	-0.020	0.934***	0,322***	-0.014	1																
Financial variables																							
7	dbacba	0.215***	0.201***	-0.201***	0.188***	0.253***	-0.230***	1															
8	llgdp	0.166***	0.235***	-0.298***	0.125***	0.287***	-0.276***	0.406***	1														
9	cbagdp	-0.104***	-0.098***	0.081***	-0.071***	-0.131***	0.092***	0.666***	-0.065***	1													
10	dbagdp	0.316***	0.375***	-0.265***	0.277***	0.453***	-0.294***	0.511***	0.798***	-0.160***	1												
11	pcrdbofgdp	0.379***	0.463***	-0.236***	0.366***	0.515***	-0.264***	0.515***	0.721***	-0.207***	0.909***	1											
12	concentr.	-0.333***	-0.190***	0.001	-0.354***	-0.254***	-0.039***	-0.183***	-0.203***	0.123***	-0.126***	-0.164***	1										
Energy variables																							
13	copr	0.096***	0.041***	-0.103***	0.065***	0.038***	-0.103***	0.001	-0.002	0.002	-0.022	0.047***	-0.132***	1									
14	prng	0.222***	0.051***	-0.077***	0.196***	0.105***	-0.087***	0.013	-0.031*	0.003	-0.041**	0.004	-0.132***	0.408***	1								
15	oilprice	0.044***	0.141***	-0.006	0.049***	0.115***	-0.030**	0.173***	0.121***	-0.141***	0.132***	0.123***	-0.013	0.020	0.039***	1							
16	gasprice	0.044***	0.135***	-0.006	0.047***	0.111***	-0.030**	0.174***	0.123***	-0.129***	0.133***	0.124***	-0.008	0.019	0.036**	0.970***	1						
17	pcenergy	0.087***	0.131***	-0.206***	0.059***	0.144***	-0.199***	0.337***	0.383***	-0.186***	0.449***	0.536***	-0.029	0.149***	0.158***	0.046***	0.045***	1					
18	pcCO2	0.008	0.094***	-0.283***	-0.028**	0.096***	-0.271***	0.326***	0.403***	-0.177***	0.434***	0.499***	-0.037*	0.153***	0.147***	0.037***	0.036**	0.962***	1				
Control variables																							
19	gdppop	0.307***	0.460***	-0.137***	0.279***	0.484***	-0.131***	0.399***	0.605***	-0.007	0.690***	0.736***	-0.078***	0.082***	0.062***	0.171***	0.163***	0.561***	0.486***	1			

20	indickd	-0.088***	-0.098***	0.265***	-0.062***	-0.126***	0.278***	-0.143***	-0.123***	-0.180***	-0.198***	0.191***	0.111***	0.097***	-0.072***	0.000	0.000	-0.125***	-0.105***	-0.117***	1		
21	pol	0.543***	0.589***	-0.011	0.504***	0.651***	-0.070	0.285***	0.295***	-0.107***	0.527***	0.549***	-0.157***	-0.011	0.011	0.059	0.059	0.104**	0.062	0.495***	-0.093***	1	
22	fdigdp	-0.020	-0.072***	-0.084***	-0.078***	-0.028*	0.002	0.061***	0.419***	-0.206***	0.143***	0.138***	-0.147***	-0.032**	-0.026**	0.074***	0.065***	0.157***	0.178***	0.290***	0.101***	0.097*	1

Table 3: Financial sector development and renewable energy capacity

This table shows the regression of financial sector development on renewable energy capacity levels. Due to a lag in some of the independent variables, the initial sample period of 29 years is reduced to 28 years. The number of observations differs per regression due to missing values in the cross-sections. The t-values are shown in parentheses. In case of a random model the dummy variable landlocked is included. The fixed effect model is corrected with GLS cross-section weights and all regressions have standard errors that are robust to serial correlation. GLS weights could not be applied in equation (6) and (12). Coefficients denoted with *** are significant at the 1% level, coefficients denoted with ** at a 5% level and coefficients denoted with * at a 10% level. The Hausman statistic is included to show whether a fixed (<0.05) or random (>0.05) model is to be preferred.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	totreic	totreic	totreic	totreic	totreic	totreic	totnhreic	totnhreic	totnhreic	totnhreic	totnhreic	totnhreic	recshare	recshare	recshare	recshare	recshare	recshare
C	0.641***	0.680***	0.720***	0.670***	0.666***	0.997***	0.023*	0.035***	-0.012	-0.030	-0.064*	0.013	0.352***	0.334***	0.291***	0.326***	0.327***	0.276***
	(43.057)	(45.000)	(70.040)	(54.008)	(51.650)	(22.365)	(1.804)	(2.604)	(-0.389)	(-0.647)	(-1.667)	(0.151)	(10.357)	(169.317)	(10.796)	(364.536)	(288.646)	(25.236)
dbacba	0.066***						0.005						-0.078***					
	(5.011)						(0.993)						(-2.972)					
Llgdp		0.076***						0.002						-0.007**				
		(3.549)						(0.184)						(-2.248)				
cbagdp			-0.030**						0.033						0.092***			
			(-2.174)						(0.697)						(3.139)			
dbagdp				0.112***						0.123						-0.001		
				(6.139)						(1.057)						(-0.847)		
pcrdbofgdp					0.113***						0.216*						-0.003*	
					(5.946)						(1.806)						(-1.936)	
concentration						-0.116***						-0.001						0.049***
						(-2.670)						(-0.013)						(3.118)
gdppop	0.000***	0.000***	0.000***	0.000***	0.000***	0.000**	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000**	0.000***	0.000**	0.000***	0.000***	0.000***
	(10.814)	(10.118)	(10.023)	(7.695)	(7.295)	(2.163)	(9.440)	(9.820)	(6.161)	(3.095)	(3.067)	(2.812)	(1.976)	(3.527)	(2.006)	(2.819)	(2.883)	(3.489)
Copr	0.000*	0.000	0.000**	0.000	0.000	-0.000	0.000*	0.000	0.000	0.000	0.000	0.000	0.000	0.000**	0.000	0.000**	0.000**	0.000
	(1.729)	(0.164)	(2.150)	(0.556)	(-0.165)	(-0.301)	(1.668)	(1.030)	(1.083)	(0.800)	(0.713)	(1.049)	(1.035)	(2.323)	(0.974)	(2.241)	(2.489)	(1.003)
Pmg	0.000***	0.000***	0.000***	0.000***	0.000***	-0.000	-0.000	0.000	0.000	0.000	0.000	-0.000***	-0.000	-0.000	0.000	-0.000	-0.000	-0.000*
	(3.288)	(4.819)	(6.164)	(4.213)	(4.697)	(-1.130)	(-1.348)	(0.879)	(0.726)	(0.349)	(0.721)	(-2.957)	(-0.753)	(-0.790)	(0.074)	(-1.065)	(-1.144)	(-1.757)
oilprice	0.000***	0.000***	0.000***	0.000***	0.000***	0.002***	0.000	0.000	0.001*	0.001*	0.001*	0.002***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***

	(4.389)	(3.561)	(4.021)	(4.161)	(4.093)	(5.015)	(1.175)	(1.186)	(1.824)	(2.019)	(1.944)	(3.163)	(-2.151)	(-2.493)	(-2.580)	(-2.832)	(-2.810)	(-3.209)
pcenergy	0.000	-0.000	0.000	-0.000	0.000**	-0.000	- 0.001***	-0.001***	- 0.001***	- 0.001***	- 0.001***	-0.000	-0.000	0.000**	-0.000	-0.000**	-0.000**	-0.000*
	(0.562)	(-0.108)	(1.119)	(-0.506)	(2.458)	(-0.237)	(-4.737)	(-4.664)	(-3,381)	(-2.748)	(-2.719)	(-0.409)	(-1.071)	(-2.321)	(-1.097)	(-2.297)	(-2.388)	(-1.664)
Lndlckd									-0.067	-0.057			0.183***		0.194***			
									(-1.616)	(-1.479)			(2.840)		(2.813)			

Table 4: Financial sector development and renewable energy capacity for high income countries

This table shows the regression of financial sector development on renewable energy generation levels for countries in the World Bank high income group. Due to a lag in some of the independent variables, the initial sample period of 29 years is reduced to 28 years. The number of observations differs per regression due to missing values in the cross-sections. The *t-values* are shown in parentheses. In case of a random model the dummy variable landlocked is included. The fixed effect model is corrected with GLS cross-section weights and all regressions have standard errors that are robust to serial correlation. Coefficients denoted with *** are significant at the 1% level, coefficients denoted with ** at a 5% level and coefficients denoted with * at a 10% level . The Hausman statistic is included to show whether a fixed (<0.05) or random (≥0.05) model is to be preferred.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	totreic	totreic	totreic	totreic	totnhreic	totnhreic	totnhreic	totnhreic	recshare	recshare	recshare	recshare
C	0.922***	1.180***	0.989***	1.214***	0.102	-0.044	-0.112	0.200***	0.201***	0.187***	0.164***	0.213***
	(17.082)	(53.137)	(40.561)	(38.526)	(0.461)	(-0.511)	(-1.107)	(5.754)	(3.734)	(4.904)	(4.161)	(41.359)
dbacba	0.227***				-0.135				-0.017			
	(4.074)				(-0.564)				(-0.414)			
cbagdp		-0.291***				0.077				-0.015		
		(-2.831)				(0.170)				(-0.439)		
pcrdbofgdp			0.171***				0.269*				0.028	
			(6.123)				(1.757)				(1.546)	
stmktcap				0.029*				0.086**				-0.002
				(1.685)				(2.432)				(-1.164)
gdppop	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000	0.000	0.000	0.000***
	(10.447)	(10.838)	(8.598)	(4.499)	(5.649)	(5.829)	(3.290)	(6.721)	(1.542)	(1.467)	(1.027)	(3.708)
fdigdp	-0.000	-0.000	-0.000	-0.000	-0.003**	-0.003	-0.002***	-0.001**	0.000	0.000	0.000	-0.000
	(-0.147)	(-0.252)	(-1.533)	(-1.619)	(-2.562)	(-1.565)	(-4.210)	(-2.399)	(0.637)	(0.874)	(0.258)	(-0.493)
gasprice	0.012***	0.013***	0.007***	0.010**	0.032**	0.032**	0.028**	0.033***	0.003**	0.003**	0.002**	0.002***
	(3.257)	(3.178)	(2.620)	(2.091)	(2.562)	(2.502)	(2.469)	(6.724)	(2.065)	(2.042)	(2.117)	(3.982)
pcenergy	-	-0.000**	-	-	-	-	-0.001**	-	-0.000	-0.000	-0.000	-

	0.000***		0.000***	0.000***	0.001***	0.001***		0.001***				0.000***
	(-2.607)	(-2.280)	(-2.728)	(-3.060)	(-2.879)	(-2.782)	(-2.515)	(-9.875)	(-1.064)	(-1.094)	(-1.559)	(-3.465)
lndlckd					-0.283**	-0.224	-0.270**		0.060	0.060	0.076	
					(-1.987)	(-2.003)	(-1.610)		(0.529)	(0.533)	(0.688)	
Observations	951	913	1027	727	951	913	1027	727	951	913	1027	727
Countries	46	46	49	43	46	46	49	43	46	46	49	43
R^2(wei)	0.997	0.998	0.998	0.998	0.448	0.464	0.411	0.982	0.131	0.136	0.155	0.997
Adj R^2(wei)	0.997	0.997	0.998	0.998	0.445	0.460	0.407	0.981	0.125	0.130	0.150	0.997
Hausman	0.001	0.001	0.001	0.000	0.304	0.396	0.366	0.036	0.217	0.244	0.157	0.012
R^2 (unw)	0.986	0.986	0.987	0.986	0.336	0.335	0.320	0.850	0.023	0.019	0.022	0.991

Table 5: Dynamic panel estimations

This table shows the results of the dynamic panel GMM estimations. The dependent variables are included with a one year lag. A two-step Arrelano and Bond estimator is used. The regressions have standard errors that are robust to serial correlation. Coefficients denoted with *** are significant at the 1% level, coefficients denoted with ** at a 5% level and coefficients denoted with * at a 10% level. The t-values are shown in parentheses. The Sargan test for over-identifying restrictions shows that the restrictions are valid.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	totreic	totreic	totreic	Totreic	recshare	recshare	recshare	recshare
dbacba	0.026***				0.001***			
	(2418.8)				(207.3)			
llgdp		0.011***				-0.017***		
		(417,.)				(-875.0)		
dbagdp			0.023***				-0.010***	
			(114.4)				(-875.0)	
pcrdbofgdp				0.012***				-0.010***
				(1459.1)				(-162.7)
gdppop	0.000***	0.000***	0.000***	0.000***	-0.000***	0.000***	0.000***	0.000***
	(2781.9)	(2539.8)	(572.1)	(5806.0)	(-58.8)	(154.0)	(265.8)	(94.4)
copr	0.000***	0.000***	0.000***	0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(843.1)	(393.6)	(31.0)	(971.3)	(-456.0)	(-5.5)	(-32.1)	(-9.5)
pmg	-0.000***			-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-690.4)			(-3286.9)	(-77.8)	(-74.1)	(-59.2)	(-24.0)
oilprice	0.000***	0.000***	0.000***	0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(1242.7)	(758.1)	(155.6)	(1821.8)	(-438.4)	(-214.3)	(-361.3)	(-117.4)
pcenergy	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-1016.2)	(-336.6)	(-216.6)	(-1809.2)	(-423.8)	(-79.5)	(-342.1)	(-73.2)

totreic(-1)	0.926***	0.900***	0.899***	0.903***				
	(180445)	(58364)	(31802)	(260442)				
rencapshare(-1)					0.850***	0.863***	0.872***	0.873***
					(59547)	(9808)	(29412)	(6510)
observations	3491	3241	3333	3208	3475	3106	3196	3193
countries	172	154	156	156	172	154	156	156
J-stat	118.408	103.204	124.102	121.563	90.380	71.982	96.056	110.729
Instrument rank	135	115	120	119	137	116	120	111
Sargan	0.717	0.612	0.224	0.253	0.997	0.998	0.874	0.308