Determinants of Renewable Energy Technology Adoption – Evidence for Developing Countries 1980–2008

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Abstract

Reducing emissions from electricity generation is frequently considered as a key aspect of climate change mitigation. While developing countries have no binding targets for the reduction of greenhouse gas emissions, they may avoid the unsustainable development path of industrialized countries by deploying renewable energy technologies (RET). In addition, they may benefit from the substantial additional socio-economic benefits of these technologies.

In this paper we use data on electricity generation from renewable energy in order to analyze the determinants of the adoption of RET in developing countries between 1980 and 2008. Our first step is to consider electricity generated from hydropower, the main source of renewable energy. The preliminary findings show that factor endowments and the level of economic development are the driving determinants of hydropower electricity generation. In a second step, we analyze non-hydropower sources of renewable energy (biomass, geothermal, solar, and wind). We find that the level of economic development, feed-in tariffs and open trade markets support the adoption of these technologies in developing countries. These results are robust to different treatments of zero-valued observations in the underlying dataset. With regard to other control variables such as human capital, openness or financial development our results are less robust. To get more robust findings, we will apply alternative regressions techniques such as Poisson specifications to adequately deal with zero -valued observations hereafter.

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1 Introduction

In recent years, the growth of global carbon emissions can almost exclusively be attributed to increases in carbon emissions from developing countries (IEA 2010).[4] Consequently, aggregate energy-related CO_2 emissions of non-Annex I developing countries have surpassed those of Annex I countries – industrialized and transition countries that ratified the Kyoto Protocol – for the first time in 2008 (IEA 2010).[5] Due to continued economic growth, which is likely to result in increased energy demand, emissions from developing countries are expected to further grow in the future (Jakob, Haller, and Marschinski 2011). Hence, limiting the future increase of emissions from developing countries is often regarded as essential to achieve ambitious climate targets (IPCC 2011).

Currently, the electricity sector constitues the major source of energy-related CO_2 emissions, accounting for 41% of global CO_2 emissions (IEA 2010). Reducing emissions from electricity generation is frequently considered a key aspect of climate change mitigation (Luderer et al. 2011), and a large variety of carbon-free energy technologies – such as hydropower, geothermal, solar, biomass and wind – are available (Newell, Jaffe, and Stavins 2006). While hydropower already enjoys wide-spread adoption as a low-cost source of electrical power, other renewables are in many cases more expensive. Hence, in many instances less costly conventional (i.e. fossil based) energy sources are given priority, even though renewable energy technologies (RET) have the potential to create substantial additional socio-economic benefits, such as reducing local air pollution, increasing energy access, and improving energy security (IPCC 2011).

As RET have been primarily developed in industrialized countries, developing economies are generally dependent on the cross-country diffusion of these technologies. So far, the drivers and barriers of technological change in the energy sector (Del Río González 2009) and the adoption of RET in developing countries have received limited attention in the literature. For this reason, this paper uses data on electricity generation from for the period 1980–2009 to identify factors which influence the adoption of RET in developing countries. We distinguish between hydropower and non-hydropower (biomass, geothermal, solar, and wind) sources of

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[4] However, the United States have not ratified the Protocol, but are one of the largest per capita emitters of CO_2 (18t) (IEA 2010).

[5] Including China and India.

renewable energy. A number of factors which have repeatedly been discussed as promoting technology adoption in the current literature are considered as explanatory variables, namely economic development, human capital, the development of financial markets, openness to trade and foreign direct investment (FDI), and, to account for the peculiarities of the renewable energy sector, local endowments and environmental policies.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. In Section 3 we introduce the data of our econometric analysis and specify the econometric model and methodology. The results of our analysis are presented and discussed in section 4. Next to our general findings, we discuss the results of the sensitivity analysis. Section 5 concludes.

2 Literature Review

The theoretical literature on endogenous technological change distinguishes between three stages of the process: invention, innovation and diffusion (Popp et al. 2011). In the invention stage, new knowledge is generated by purposeful investments – for instance, into research and development (R&D) – which require capital as well as skilled researchers (Popp et al. 2011). Innovation denotes the commercialization of an invention, i.e. the supply of the technology on the market. The process that leads to the adoption or adoption of a new technology by other individuals, firms or countries is called diffusion. Technological change occurs only as a technology is increasingly being deployed, rather than upon its invention (Popp et al. 2011).

Empirically, technology can be measured in quite distinct ways that implicitly subscribe to particular theories of the process of technological change or that reflect selective interest in particular stages of it. Technology can be measured by measuring inputs (e.g. R&D investments), outputs (e.g. patents), or the effect of a technology (e.g. factor productivity) (Keller 2004). At a more disaggregate level technology can also be measured by specific metrics applicable to its output. Comin and Hobijn (2003) use, inter alia, numbers of newspapers, radios and televisions per capita as disaggregate measures of mass communication technology. Similarly, the amount of electricity in Watt-hours produced from renewable energy sources is a natural measure of RET.

The channels and the factors that drive or impede the diffusion process, however, are not yet fully understood and are likely to differ depending on the gaps that need to be bridged between the original inventor or supplier of a technology and its final users or adopters. We are particularly interested in the drivers and barriers to cross-country or international technology diffusion.[6] An overarching issue that affects technology diffusion via markets is that the characteristics of technology are similar to those of public goods (see e.g. (Keller 2004). The associated knowledge spillovers imply a failure of markets to provide optimal levels of technology, both in terms of initial inventions as well as in terms of diffusion.

Grübler (2003) reviews general technology diffusion patterns for a variety of technologies, which follow a similar S-shaped pattern of diffusion starting from slow growth that eventually slows down when markets are saturated. Based on a variety of theoretical considerations, he suggests four classes of micro-level factors governing the diffusion process: (1) the perceived relative advantage, (2) the compatibility of a new technology with existing social values, practices, techniques and infrastructure, (3) the complexity of a technology, and (4) the uncertainty related to the benefits from a technology.

Keller (2004) reviews the empirical evidence on international technology diffusion. He cites evidence that imports as well as foreign direct investment (FDI) contribute to international technology diffusion in studies that measure technology diffusion via "technology output" in the form of increases in productivity. He also finds that the distance between the source and receiving country has a negative effect on technology diffusion, while factors representing the notion of absorptive capacity such as human capital and domestic investments in R&D seem to have a positive impact on technology adoption.

Using a panel that covers 25 technologies in 23 OECD countries from 1788–2001, Comin and Hobijn (2004) confirm Keller's (2004) findings regarding the positive impact of a country's human capital endowment on the speed of technology adoption. In addition, they show that the type of government, the degree of trade openness and the adoption of predecessor technologies significantly affect technology adoption. Interestingly, an effective legislative is found to delay the adoption of technologies, which is explained by vested interest theory.

The diffusion of technologies for broader samples of countries has, for instance, been studied by Caselli and Coleman (2001), who also use micro-measures of technology – in this case imports of computer equipment. They also find evidence that technology adoption is

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[6] Many studies have dealt with the determinants of earlier stages of the technological change process, namely with factors affecting the rate and direction of invention and innovation. We do not include a comprehensive review of these studies here, since our interest is in effective technological change, i.e. in adoption of new technologies rather than in their development or in the spread of bare ideas. Del Rio Gonzales (2009) offers a useful review and classification of empirical analysis on environmentally relevant technologies distinguishing between the stages of invention/innovation and diffusion/adoption as well as between national vs. international diffusion studies.

enhanced by higher levels of human capital as well as by trade openness vis-à-vis OECD countries. Furthermore, they find that high investment rates, strong property rights, and a small share of agriculture in gross domestic product (GDP) positively affect computer technology adoption. Finally, they find some evidence for a negative effect from large government shares in GDP and some evidence for a positive effect of manufacturing shares. Further, Hoekman et al. (2005) point out that too little attention has been paid to the role that labour turnover and movement of people may have on cross-country technology transfer.

In contrast to most of the technologies discussed above, the use of RET is related to positive global as well as local externalities, including climate change mitigation, improved public health due to reductions in air pollution, increased energy security, and the potential to improve energy access, etc. (IPCC 2007; Recipes 2006). These aspects are of particular importance for the diffusion of RET, because they will reduce the impact of market forces in providing the optimal amount and direction of technological change, unless policies are in place that internalize these externalities (Newell et al. 1999).[7] , (Barker et al. 2007) point out that besides technology-specific factors (performance, cost, consumer acceptance, safety and financial risks), the following factors are crucial for the diffusion of low-carbon technologies: (1) available financing instruments, (2) enabling infrastructure, (3) incentives for firms, (4) regulatory compliance, and (5) environmental impacts.

Peterson (2007) surveys the empirical literature dealing specifically with greenhouse gas (GHG) mitigation through enhanced technology transfer. She finds little empirical evidence for the quantitative GHG mitigation effect from trade, FDI, official development aid and other sources of funding such as the Global Environment Facility (GEF) or the Clean Development Mechanism (CDM).

Dechezleprêtre et al. (2011) analyze the dynamics and worldwide diffusion of 13 technologies with GHG mitigation potential[8]. Their analysis highlights that inventions of climate relevant technologies are highly concentrated in a few developed countries, particularly in Japan, Germany and the United States and that these inventions have also diffused to other countries, particularly to OECD countries. They find a role for environmental and climate policies in accelerating the pace of innovation.

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[7] For instance, if emitting GHGs is costless, there is no incentive to develop low-carbon technologies, let alone their introduction to the market.

[8] Note that the use of patents to measure technology diffusion exclusively assesses the diffusion of ideas, but does not provide information on the actual adoption of the patented technologies

Popp et al. (2011) focus their empirical analysis of patenting activity specifically on the factors affecting the adoption of RE technologies. Their panel spans of 26 OECD countries from 1991–2004. They find a robust, but small effect of knowledge on renewable energy adoption. Moreover, they find that global climate policy – more specifically, ratification of the Kyoto Protocol – plays an important role for RET adoption, while they do not find significant effects for national renewable energy support policies[9]. Expectations about future electricity demand, proxies for energy security and levels of production of fossil fuels are found to be insignificant. The effect of deploying other low-carbon substitutes like nuclear and hydropower is significant, but small.

Brunnschweiler (2010) – the paper most closely related to this study – systematically analyzes the importance of financial sector development for the adoption of RET for non-OECD countries. Her findings suggest a positive association between electricity generation from RET technologies and commercial banking. Moreover, she finds that the adoption of the Kyoto Protocol in 1998 has contributed to RE adoption in these countries. Reducing the sample to non-high-income non-OECD countries does not change her baseline conclusions.

In this paper, we go a step further by taking into account a wide range of determinants for the adoption of RET, including endowments with human capital, financial development, trade and foreign direct investment, as environmental regulation.

3 Data

We concentrate our analysis on the power sector and use data on electricity generation from renewable energy to proxy for the adoption of RET in developing countries as defined by Beck et al. (2009). Data on electricity generation from renewables is freely available from the U.S. Energy Information Administration (EIA) for the years 1980–2009. As data on renewable energy production is not complete for all countries in 2009, we drop the observations from this year.

As the major source of RET electricity generation is hydropower, we distinguish between hydropower and non-hydropower sources of electricity generation. Unfortunately, we cannot distinguish between large and small scale hydropower projects.[10] We have data for 146 developing countries. Out of these countries 114 (78%) produce electricity from hydropower

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[9] However, using patent data for 25 OECD countries over the period 1978–2005, Johnstone et al. (2009) suggest that public policy plays a significant role on innovation in RE technologies.

[10] As large hydropower projects may have serious environmental and social implications, they are partly not considered as sustainable RET (Brunnschweiler 2010).

in at least one year of the sample period (see Table 1). Asia and Europe are the regions with the highest percentage of developing countries with electricity generation from renewables. About 62 countries (42%) produce renewable energy from non-hydro sources in at least one year of the sample period. The region with the highest share of developing countries that produce electricity from non-hydropower is Latin America (including the Caribbean), followed by Europe. Overall, this general statistics points out that there a many countries – especially if non-hydropower is considered – with zero-valued observations.

Table 1: Number of Countries with Electricity Generation from RET and Non-Hydro Power 1980-2008

	number of countries (% of countries within region)	
region	H	NH
Asia	24 (92%)	16 (62%)
Europe	11 (92%)	10 (83%)
Latin America and the Caribbean	25 (74%)	20 (59%)
Middle East and North Africa	11 (79%)	6 (43%)
Oceania	3 (27%)	0 (0%)
Sub-Saharan Africa	40 (84%)	10 (20%)
total number of countries (% in region)	114 (79%)	62 (42%)

Source: Own Calculation Based on EIA data.

Table 2 shows the mean share of electricity generation from hydropower to total electricity generation (*HS*) and mean hydropower electricity generation per capita (*HPC*) in developing countries over the period 1980–2008. The mean share of hydropower is 35% which seems to be relatively high. The reason is that smaller countries with high shares of hydropower are also included in the data. If we account for the size of countries, the mean share of hydropower is about 10% (*relative HS*). In per capita terms, electricity generation from hydropower is about 320 kwh per capita in developing countries. Paraguay (1987–2008) and Bhutan (2005–2008) produce electricity from hydropower about more than 4.000 kwh per capita. Compared to electricity generated from hydropower, the share of non-hydropower to total electricity generation (*NHS)* and non-hydropower electricity generation per capita (*NHPC*) is small (1% respectively 6.7 kwh per capita).

Table 2: Hydropower and Non-Hydropower Electricity Generation in Developing Countries, 1980–2008

Variable	Obs	Mean	Std. Dev.	Min	Max
HPC	4004	314.36	818.95	0.00	10351.45
HS	4004	0.35	0.36	0.00	1.00
relative HS	3980	0.10	0.11	0.00	0.37
NHPC	4004	6.74	25.73	0.00	350.88
NHS	4004	0.01	0.04	0.00	0.40

Notes: H = hydropower, NH = non-hydropower, PC = per capita, S = share; Source: EIA.

3.1 Control Variables

The control variables included in the estimates are based on our theoretical considerations. Table 3 summarizes the control variables included in our analysis. Our choice of control variables is necessarily selective. As outlined in our literature review, a variety of factors is being scrutinized to understand their effects on the adoption of RET. The most notable feature of RET – in contrast to other technologies – seems to be that the core benefits of their adoption are public rather than private ones, i.e. related to externalities. As long as the public benefits of RET adoption are incompletely internalized, market forces will impede rather than enhance RET adoption, since fossil-fuel alternatives often entail lower private costs. For this reason – and because of serious limitations in data availability – we chose to test the relative importance for RET adoption of selected proxies that fall within three broad categories: 1) local endowments of hydropower 2) regulatory policies, and 3) commonly discussed drivers of technology adoption. As we consider non-hydropower in general and do not distinguish between different energy sources, we only control for local endowments with regard to hydropower. However, the applied econometric methodology allows us to control for time-constant endowments of non-hydropower sources across countries (see Section 3.2). Overall, our approach allows us to focus on a palatable number of variables, which are discussed in more detail below.

Table 3: Summary Statistics of Control Variables, 1980–2008

Variable	Obs	Mean	Std. Dev.	Min	Max
hydropot	3045	118.42	324.17	1.00	2474.00
feed-in tariff	4234	0.03	0.16	0.00	1.00
gdppc	3362	3956.66	3446.76	150.81	20098.27
rule of law	1720	-0.54	0.69	-2.68	1.29
regulatory quality	1720	-0.49	0.73	-2.68	1.64
trade	3366	76.80	41.52	0.31	375.38
fdi	3218	3.15	6.29	-82.89	90.74
enrollment rate	3014	95.78	25.39	13.77	232.84
completion rate	2041	72.37	27.58	0.00	150.36
assets	3098	73.17	23.10	1.73	126.45
liabilities	2571	24.36	20.67	0.11	165.96

Notes: hydropot = hydro-power potential; gdppc = GDP per capita;
rule of law, regulatory quality = governance indicators;
fdi = FDI net inflows in percent of GDP; trade = trade in percent of GDP;
enrolment rate = primary school enrolment as a percent of gross enrolment;
completion rate = primary completion rate in percent of relevant age group;
assets = ratio of deposit money bank assets to central bank assets;
liabilities = ratio of liquid liabilities to GDP

3.1.1 Local Endowments with Renewable Energies

Local endowments with renewable sources are undoubtedly an important determinant of investments in RET. To account for the country-specific potential of hydropower, we use country-specific data of the technically exploitable capability (*hydropot*), i.e. the gross theoretical capability that can be exploited with current technology, from the 2010 World Energy Council Survey of Energy Resources.[11] As we consider aggregate non-hydropower sources of renewable energy, we do not explicitly control for endowments. However, ur econometric methodology allows us to control for these time-constant factors.

3.1.2 Regulatory Policies

RET are in general less environmentally harmful than fossil-fuel based electricity supply, e.g. due to reduced or no local air pollution and low life-cycle GHG emissions (IPCC 2011). However, it is unclear to which extent RET adoption is perceived as a valid and appropriate solution to local or global environmental problems in developing countries. Moreover, it is an empirically open question what kinds of environmental regulation will have a measurable impact on technological change towards more environmental friendly production (Del Río González 2009). This is also true for the more specific case of RET.

We therefore look at the impact of the introduction of a feed-in tariff as one of the allegedly most successful RET-specific support policies. During the period 1998–2005 and especially during 2005–2010 more and more countries, states and provinces implemented policies to promote investments in RET. In 2010, at least 42 developing countries had a policy to promote power generation from renewables. Feed-in tariffs are considered as one particularly successful policy instrument; though a variety of other policy measures have been implemented in different countries (IPCC 2011). Overall, these policies are widely considered to have promoted innovation of and investments in RET, with the largest effect on wind power, and less so on solar, biomass and small hydropower (REN21 2011). We include a dummy variable which is 1 if a country (state or province of a country) had enacted a feed-in tariff policy in a given year (and the following years) and 0 otherwise (*feed-in tariff*). Our sample includes 22 countries which have implemented a feed-in tariff over the sample period. Data on feed-in policies is sourced from the REN21 2011 Renewables Global Status Report. It allows us to identify the year of implementation of feed-in tariffs in each province or country, but not whether the tariff is directed towards a particular RET.[12]

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[11] The Survey of Energy Resources is published every three years. The observed changes of the data of hydropower potential in some countries may mainly be attributed to better estimation methods than changes of hydropower potential. Hence, we use the most recent data from 2008 on the technically exploitable capability of hydropower.

[12] We take the classification of REN21, even if some of them are discussable. For example, the feed-in tariff of Indonesia (2002) is very low and may not be considered as a true feed-in tariff. Some policies were not continued after their enactment such as in Brazil (2002-2010). India's feed-in tariff from 1993 has not been substantially continued (REN21 2011).

3.1.3 Commonly Discussed Drivers of Technology Adoption

Economic Development

We expect that countries start to invest in RET along with their economic development as they become richer. Moreover, with a higher level of economic development environmental protection is more valued. This may lead to stronger environmental regulations and encourage the adoption of RET. As countries become richer, they are also able to afford more environmental technologies (Del Río González 2009; Plassmann and Khanna 2006).

We control for the level of economic development by the log of GDP per capita in constant 2005 US$ (*log gdppc*) as a standard determinant of RET adoption in all our specifications.

Governance

The governance environment may affect the general investment conditions in a country. We control for the governance by looking at the following to measures provided by Kauffman et al. (2010): (1) While the variable *rule of law* measures agents' confidence with regard to contract enforcement, property rights or judiciary, (2) the variable *regulatory quality* captures the policy and regulatory environment that are relevant for private sector development. The data are available from 1996 onwards, but are missing for 1997 and 2001. We substituted these missings with data from the previous year.

Openness to Foreign Direct Investment and Trade

FDI and trade have been broadly discussed as drivers for technology adoption in general, though the evidence for FDI is mixed (see section 2). In summarizing the literature on the diffusion of environmental friendly technologies, Del Río González (2009) states that foreign direct investment and trade may facilitate the diffusion of environmental friendly technologies. We expect that openness to FDI and trade will also have a positive impact on the adoption of RET in developing countries, though the broad measures available do not allow us to infer any insights into the openness to FDI and trade in the RET sector in particular. As the descriptive statistics of FDI show, we also have negative values, which indicate that there are more disinvestments than new investment inflows in certain countries. We control for FDI net inflows in percent of GDP (*log fdi*) and trade in percent of GDP (*log trade*).[13]

[13] We also considered applied tariff rates as control variables, but because of limited data for this variable, we loose a very large number of observations which does not seem to be reasonable.

Human Capital

Human capital can be defined as "the knowledge, skills, competences and other attributes embodied in individuals that are relevant to economic activity" (OECD 2001). It has been found to play an important role in the adoption of many innovative technologies and the associated productivity growth (see section 2). It should, therefore, be interesting to find out whether higher human capital endowments also have a discernible positive effect on RET adoption.

We measure human capital endowments by primary school enrolment as a percent of gross enrolment (*log enrolment*) and primary completion rate in percent of relevant age group (*log completion*). The gross primary enrolment ratio relates total enrolment in primary school – regardless of age – to the population of the age group that officially corresponds to the level of education shown (World Bank 2007). Primary completion rate is defined as the ratio of the total number of students which complete the last year of primary school (excluding repeaters) to the total number of children of official graduation age. In our sample, the mean of primary enrolment rate is 96% and of completion rate 72%. The World Bank acknowledges the importance of primary education as a precondition to future learning and for higher education levels. Within this context, higher completion rates are more important than higher enrolment ratios as at least five to six years of schooling are considered as a threshold for the development of basic competencies (Bruns et al. 2003).

Financial Development

Financial sector development has been suggested as being of particular importance for the adoption of RET (Brunnschweiler 2009), (Lindlein and Mostert 2005). Due to the relatively higher upfront costs of most RET (except for biopower) compared to fossil-fuel based power plants (IPCC 2011), good access to finance can be considered relatively more important for most RET than for fossil-fuel based power generation technologies. Hence, the share of RET in total power production is also likely to increase with financial sector development. Our model is not set up to test the impact of financial sector development on the shares of RET in the power sector. We do, however, expect a positive association between financial sector development and total adoption of RET per capita.

In line with Brunnschweiler (2009), we test for the importance of the level of financial development for investments in RET using different measures: The ratio of deposit money bank assets to central bank assets (*log assets*) measures financial development with regard to the importance of commercial banks compared to central banks. A higher importance of commercial banks indicates a higher level of financial development. The size of the financial system of each country is captured by the ratio of liquid liabilities to GDP (*log liabilities*). This variable is a broad measure of financial depth as it includes all banks, bank-like and other financial institutions (Beck et al. 2009).

3.2 Econometric Models and Methodology

In a first step, we concentrate on electricity generation from hydropower and specify the following unobserved effects model in logs:

$$\log(HPC_{jt}) = \beta_0 + \beta_1 \log(hpot_{jt}) + \beta_2 \log(gdppc_{jt}) + \beta_3 (feedintariff)_{jt} + \beta_{4i} \log(X_{jt}) + a_i + u_{it} \quad (1)$$

Our first measure log(HPC_{jt}) is the log of electricity generation from hydropower in kwh per capita in country j in year t. Depending on the applied econometric methodology, we account for hydropower resources/potential (*hypot*). In all our specifications, we control for the log of GDP per capita log($gdppc_{jt}$) and *feed-in tariff*. We then specify different models to analyze our time-varying control variables *openness*, *human capital* and *financial development*. The combined error term is given by: $\varepsilon_{jt} = \alpha_j + u_{jt}$ with the unobserved, time-constant country effects α_j and the idiosyncratic error u_{jt}.

Our second step is to use the log of electricity generation from non-hydro power (geothermal, wind, solar, tide and wave, biomass and waste) in kwh per capita in country j in year t (log($NHPC_{jt}$)) as the dependent variable:

$$\log(NHPC_{jt}) = \beta_0 + \beta_1 \log(gdppc_{jt}) + \beta_2 (feedintariff)_{jt} + \beta_{3i} \log(X_{jt}) + a_i + u_{it} \quad (1)$$

As we consider NHPC aggregately, we do not explicitly control for local endowments of these renewable energy sources. We specify our models in logs in order to account for the fact that electricity generation from renewable energy can never be negative and is not normally distributed. By taking logs, we get a distribution that is closer to normal. Another advantage of our approach is that taking logs allows us to explain the very broad range of data including these countries. We have about 31 (84) countries that do not produce electricity from RET (non-hydropower) over the whole sample period. These zero observations are a dropped if we take logs as the logarithm of zero is undefined. To avoid this problem, we add a small positive constant to our dependent variables: *log(0.1+HPC)* respectively *log(0.001+NHPC)*. This approach has been suggested by Wooldridge (2009) and is also used, for example, in the context of the gravity model of trade that also has to deal with zero-valued observations (Linders/de Groot (2006). While this procedure avoids a sample selection bias, but has the drawback that the inserted constant “is arbitrary and does not necessarily reflect the underlying expected value.” (Linders/de Groot (2006). However, we carefully chose the positive constants depending on the dimensions of the two dependent variables and added only a very small amount.

We specify our log-normal model with Random Effects (RE) and Fixed Effects (FE).[14] RE can be used under the assumption that the unobserved effect is purely random and uncorrelated with the explanatory variables. Compared to a pooled model, a generalized least squares RE transformation eliminates the serial correlation in the composite error term. Alternatively, to account for unobserved heterogeneity across countries, a FE transformation is used. As the fixed effect α_j is eliminated with this method, the estimators of the coefficients are unbiased and consistent, even if the country-specific effect is correlated with the explanatory variables. The FE estimator requires the assumption of strict exogeneity to hold; in other words, the explanatory variables and the idiosyncratic error should not be correlated in any time period. While we control for time fixed effects in the FE models, we add regional dummies for Asia, Sub-Saharan Africa, Latin America and the Caribbean as well as the Middle East and North Africa in the RE models.

We apply a test of overidentifying restrictions by Schaffer und Stillman (2006) to test if the country-specific effects are uncorrelated with the regressors, i.e. the appropriateness of the RE model. The test is similar to a Hausman test (Hausman 1978), but has the advantage of still being applicable in the event of heteroskedastic and clustered errors which are used to correct for heteroskedasticity and within-country serial correlation.

[14] By using the Breusch-Pagan Lagrange multiplier (LM) test for RE we find that there are significant differences across countries (Breusch and Pagan 1979). Hence ordinary least squares in not appropriate and we have to use panel data models.

4 Regression Results

4.1 Generall Findings

Hydropower

Table 4 presents different specifications if hydropower is the determinant variable. We concentrate on the estimation results using RE, and control for country-specific endowments of hydropower.[15] Our findings clearly show that the level of economic development (*log gdppc*) and hydropower potential (*log of hydropot*) are the driving determinants of hydropower adoption. Unexpected findings are the negative coefficients of *feed-in tariff* in all specifications. This may be explained by the fact that hydropower is already commercial and investments may be less dependent on regulatory policies. We find a positive and significant coefficient for one of our measures of human capital (*log completion rate*). All other control variables are not significant. Overall, our results suggest that the adoption of hydropower technologies is mainly driven by hydropower potential and may increase with higher level of economic development.

We also estimated these models using FE. As our measure of hydropower potential is time-constant, we cannot include this variable in the estimations, but apply country-specific fixed effects. The FE results slightly differ from the ones presented above as the coefficient of the 2nd quartile of *regulatory quality* is negative and significant, but the coefficient of *log completion rate* is not significant anymore. The Sargan-Hansen test statistic suggests that in the RE estimator is only consistent and efficient in some cases. However, as the results of the FE and RE estimation do not differ too much, a concentration on the RE results while controlling for factor endowments seems to be appropriate.

Non-Hydropower

As we consider non-hydropower sources of renewable energy aggregately and we cannot explicitly control for time-constant factor endowments, our focus is on the FE estimation now. However, we compare these results with those of a RE specification. Overall, we find a positive and significant association of non-hydropower with *log gdppc* and *feed-in tariff* in most cases (Table 5). The quartiles of *law* and *regulatory quality* enter negatively suggesting that the bad governance environment in many developing countries reduce or impede

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[15] The results of the FE specification are presented in
Table A 2 in the Appendix.

investments in non-hydropower. The positive and significant coefficients for *log fdi* and *log trade* suggest that open markets facilitate the adoption of non-hydropower technologies. Concerning the importance of financial sector development or human capital endowment on the adoption of hydropower technology, we cannot confirm a robust positive association (see Table A 3 in the Appendix).

Table 4: Hydropower - Log-Normal Random Effects Specification – Including Zero-Valued Observations

	HRE1 coef/t	HRE2 coef/t	HRE3 coef/t	HRE4 coef/t	HRE5 coef/t	HRE6 coef/t	HRE7 coef/t	HRE8 coef/t	HRE9 coef/t
log gdppc	1.328***	0.540***	0.552***	1.241***	1.178***	0.995***	0.721**	1.340***	1.117***
	(3.164)	(3.283)	(3.265)	(2.750)	(3.108)	(3.491)	(2.411)	(3.115)	(2.895)
feed-in tariff	-0.442**	-0.076	-0.071	-0.428**	-0.425***	-0.322**	-0.271**	-0.465**	-0.338**
	(-2.356)	(-0.977)	(-0.942)	(-2.302)	(-2.688)	(-2.514)	(-2.220)	(-2.207)	(-2.464)
log of hydropower potential	0.459***	0.485***	0.489***	0.465***	0.496***	0.429***	0.443***	0.429***	0.450***
	(4.781)	(5.184)	(5.284)	(4.831)	(5.106)	(4.987)	(5.094)	(4.551)	(4.804)
law (2nd quartile)		-0.061							
		(-0.868)							
law (3rd quartile)		0.003							
		(0.020)							
law (4th quartile)		-0.379							
		(-1.324)							
regulatory quality (2nd quartile)			-0.126						
			(-1.618)						
regulatory quality (3rd quartile)			-0.128						
			(-1.264)						
regulatory quality (4th quartile)			0.025						
			(0.137)						
log FDI				0.019					
				(0.675)					
log trade					0.155				
					(1.065)				
log enrolment rate						0.706			
						(1.580)			
log completion rate							0.788**		
							(2.294)		
log assets								0.103	
								(0.519)	
log liabilities									-0.064
									(-0.508)
Asia	0.090	0.169	0.119	0.098	0.027	0.270	0.185	0.221	0.133
	(0.160)	(0.308)	(0.217)	(0.174)	(0.049)	(0.509)	(0.336)	(0.381)	(0.229)
Latin America & Carribean	0.232	1.079*	1.074*	0.297	0.336	0.479	0.395	-0.020	0.738
	(0.307)	(1.925)	(1.894)	(0.388)	(0.481)	(0.788)	(0.599)	(-0.025)	(1.135)
Middle East & North Africa	0.413	1.078**	1.033**	0.460	0.527	0.664	0.785*	0.395	0.548
	(0.743)	(2.181)	(2.020)	(0.797)	(0.986)	(1.543)	(1.667)	(0.676)	(0.919)
Sub-Saharan Africa	-0.864	-0.182	-0.212	-0.882	-0.874	-0.703	-0.815	-1.022	-0.835
	(-0.480)	(-0.087)	(-0.102)	(-0.488)	(-0.492)	(-0.384)	(-0.458)	(-0.569)	(-0.459)
_cons	-16.983***	-11.516***	-11.683***	-16.465***	-17.310***	-16.970***	-15.288***	-16.765***	-14.966***
	(-4.791)	(-5.066)	(-5.057)	(-4.478)	(-5.250)	(-5.078)	(-4.881)	(-4.232)	(-4.607)
Number of observations	2,567	1,281	1,281	2,240	2,515	2,165	1,518	2,296	2,009
r2_o	0.369	0.345	0.348	0.369	0.372	0.380	0.387	0.392	0.400
r2_w	0.104	0.033	0.024	0.085	0.090	0.076	0.066	0.100	0.050
r2_b	0.401	0.367	0.370	0.405	0.416	0.433	0.428	0.411	0.422

note: *** p<0.01, ** p<0.05, * p<0.1

Table 5: Non-Hydropower - Log-Normal Fixed and Random Effects Specification – Including Zero-Valued Observations I

	NHFE1 coef/t	NHRE1 coef/t	NHFE2 coef/t	NHRE2 coef/t	NHFE3 coef/t	NHRE3 coef/t	NHFE4 coef/t	NHRE4 coef/t	NHFE5 coef/t	NHRE5 coef/t
log gdppc	1.802***	1.672***	2.348***	2.003***	2.288***	1.902***	1.933***	1.735***	1.695***	1.577***
	(3.687)	(3.830)	(3.966)	(4.481)	(3.680)	(4.172)	(3.545)	(3.727)	(3.734)	(3.920)
feed-in tariff	2.315***	2.384***	1.019*	1.167**	0.968	1.147*	2.071***	2.174***	2.156***	2.256***
	(3.535)	(3.665)	(1.715)	(1.986)	(1.624)	(1.942)	(3.112)	(3.296)	(3.307)	(3.487)
law (2nd quartile)			-0.934**	-0.835**						
			(-2.358)	(-2.172)						
law (3rd quartile)			-1.430***	-1.292***						
			(-2.832)	(-2.686)						
law (4th quartile)			-1.378**	-1.258**						
			(-2.458)	(-2.404)						
regulatory quality (2nd quartile)					-0.680**	-0.552*				
					(-1.989)	(-1.708)				
regulatory quality (3rd quartile)					-0.846**	-0.644				
					(-1.976)	(-1.589)				
regulatory quality (4th quartile)					-0.943*	-0.707				
					(-1.906)	(-1.499)				
log FDI							0.112**	0.110**		
							(2.282)	(2.300)		
log trade									0.671**	0.569*
									(2.060)	(1.847)
Asia		0.115		0.202		0.162		0.092		0.047
		(0.174)		(0.227)		(0.186)		(0.133)		(0.068)
Latin America & Carribean		-0.769		-0.757		-0.688		-0.751		-0.796
		(-0.782)		(-0.708)		(-0.634)		(-0.711)		(-0.796)
Middle East & North Africa		2.827***		2.255*		2.346**		2.676***		2.863***
		(2.785)		(1.928)		(2.013)		(2.585)		(2.771)
Sub-Saharan Africa		-1.725***		-2.163***		-2.422***		-1.826***		-1.967***
		(-4.222)		(-4.108)		(-4.599)		(-4.239)		(-4.457)
_cons	-18.768***	-18.437***	-21.949***	-19.721***	-21.787***	-19.296***	-19.717***	-18.931***	-20.724***	-20.050***
	(-4.883)	(-5.671)	(-4.653)	(-6.049)	(-4.410)	(-5.792)	(-4.584)	(-5.468)	(-5.281)	(-5.950)
Number of observations	3,286	3,286	1,625	1,625	1,625	1,625	2,866	2,866	3,183	3,183
r2_o	0.158	0.270	0.145	0.225	0.139	0.232	0.155	0.261	0.111	0.234
r2_w	0.131	0.131	0.117	0.117	0.100	0.098	0.153	0.152	0.145	0.144
r2_b	0.149	0.291	0.141	0.232	0.135	0.241	0.135	0.268	0.098	0.252
time fixed effects?	NO		NO		NO		NO		YES	
Sargan-Hansen statistic		6.200		36.578		40.952		19.048		27.328
p-value		0.045		0.000		0.000		0.000		0.000

note: *** p<0.01, ** p<0.05, * p<0.1

4.2 Sensitivity Analysis

As outlined in section 3.2, we include countries that do not produce electricity from renewables by adding a small positive constant to our dependent variables before taking logs. But as Burger et al. (2009) show, the values of the regression coefficients may vary greatly depending on the constant added. Therefore, alternatively, we follow the most common solution in the estimation of the gravity model of trade and reduce the sample to non-zero observations (Linders/de Groot 2006).

Table 6: Hydropower - Log-Normal Random Effects Specification
– Omission of Zero-Valued Observations

	HRE1 coef/t	HRE2 coef/t	HRE3 coef/t	HRE4 coef/t	HRE5 coef/t	HRE6 coef/t	HRE7 coef/t	HRE8 coef/t	HRE9 coef/t
log gdppc	0.784***	0.350**	0.354**	0.615***	0.678***	0.776***	0.550**	0.693***	0.694***
	(3.803)	(2.477)	(2.503)	(4.463)	(3.266)	(3.850)	(2.169)	(4.690)	(3.947)
feed-in tariff	-0.208**	0.000	-0.007	-0.161*	-0.238**	-0.216**	-0.157*	-0.176**	-0.197**
	(-2.027)	(0.003)	(-0.107)	(-1.914)	(-2.283)	(-2.141)	(-1.665)	(-2.162)	(-2.357)
log of hydropower potential	0.303***	0.360***	0.361***	0.313***	0.343***	0.254***	0.274***	0.275***	0.281***
	(4.231)	(4.590)	(4.609)	(4.287)	(4.743)	(4.259)	(4.478)	(4.412)	(4.493)
law (2nd quartile)		-0.061							
		(-0.864)							
law (3rd quartile)		-0.116							
		(-1.076)							
law (4th quartile)		-0.108							
		(-0.890)							
regulatory quality (2nd quartile)			-0.137*						
			(-1.783)						
regulatory quality (3rd quartile)			-0.121						
			(-1.589)						
regulatory quality (4th quartile)			-0.090						
			(-0.871)						
log FDI				0.020					
				(1.247)					
log trade					0.244**				
					(2.016)				
log enrolment rate						0.453			
						(1.589)			
log completion rate							0.382		
							(1.502)		
log assets								-0.010	
								(-0.162)	
log liabilities									0.061
									(1.067)
Asia	0.175	0.302	0.285	0.241	0.086	0.354	0.424	0.458	0.329
	(0.393)	(0.666)	(0.628)	(0.523)	(0.196)	(0.928)	(1.078)	(1.098)	(0.785)
Latin America & Carribean	0.400	1.000*	0.990*	0.599	0.409	0.261	0.327	0.345	0.837*
	(0.685)	(1.774)	(1.730)	(1.111)	(0.697)	(0.452)	(0.534)	(0.605)	(1.778)
Middle East & North Africa	0.718*	1.234***	1.225***	0.874**	0.763*	0.675*	0.878**	0.831**	0.831**
	(1.831)	(3.070)	(3.039)	(2.396)	(1.858)	(1.716)	(2.190)	(2.286)	(1.972)
Sub-Saharan Africa	1.345*	1.821*	1.838*	1.403*	1.225	1.342**	1.361*	1.347*	1.326*
	(1.778)	(1.867)	(1.934)	(1.753)	(1.479)	(2.152)	(1.933)	(1.835)	(1.794)
_cons	-8.764***	-6.842***	-6.868***	-7.734***	-9.876***	-9.581***	-7.922***	-7.382***	-7.741***
	(-4.185)	(-3.960)	(-3.971)	(-4.270)	(-4.522)	(-4.147)	(-4.041)	(-4.028)	(-3.990)
Number of observations	2,378	1,209	1,209	2,085	2,339	2,006	1,407	2,124	1,857
r2_o	0.384	0.376	0.374	0.398	0.394	0.399	0.403	0.413	0.440
r2_w	0.111	0.042	0.045	0.092	0.127	0.134	0.085	0.085	0.092
r2_b	0.383	0.371	0.368	0.383	0.398	0.417	0.417	0.406	0.449
note: *** p<0.01, ** p<0.05, * p<0.1									

The results of the RE specification presented in Table 6 again show that hydropower electricity generation is positively and significantly associated with *log gdppc* and *log hydropot*. The coefficients of the 2nd and 3rd quartile of regulatory quality are negative and significant, while the 4th quartile is negative, but not significant. In contrast to our previous results including zero-valued observations, the coefficient of *trade* is positive and significant now, but the one of completion rate is not.

Table 7 includes the estimation results for non-hydropower as determinant variable leaving out zero-valued observations. These specifications show that our general findings for *log gdppc* and *feed-in tariff* are relatively robust. As in our previous specifications using all observations, our results suggest that a bad governance environment may limit the adoption of non-hydropower. While the coefficients of *log fdi* are not significant in the FE specification, *trade* enters positively and significant in all the FE and RE specification again. As Table A 4 in the Appendix shows, our results with regard to financial development and human capital are not affected by the modification of the sample.

Our results reflect that the treatment of zero-valued observations of renewable energy electricity generation is important. Both applied methodologies have drawbacks, but overall, we find robust results of a positive association of hydropower electricity generation and the level of economic development as well as local endowments. Moreover, for non-hydropower, our findings suggest a robust positive association between the level of economic development and feed-in tariffs in developing countries.

Table 7: Non-Hydropower - Log-Normal Fixed and Random Effects Specification I – Omission of Zero-Valued Observations

	NHFE1 coef/t	NHRE1 coef/t	NHFE2 coef/t	NHRE2 coef/t	NHFE3 coef/t	NHRE3 coef/t	NHFE4 coef/t	NHRE4 coef/t	NHFE5 coef/t	NHRE5 coef/t
log gdppc	2.311***	2.185***	1.196**	1.852***	1.367**	1.869***	2.563***	2.139***	2.367***	1.811***
	(3.272)	(4.363)	(1.962)	(5.091)	(2.136)	(5.081)	(3.710)	(4.391)	(3.948)	(4.095)
feed-in tariff	0.775*	0.962**	0.079	0.307**	0.058	0.264*	0.772*	0.925**	0.671*	0.769**
	(1.772)	(2.450)	(0.563)	(2.523)	(0.384)	(1.928)	(1.764)	(2.417)	(1.733)	(2.164)
law (2nd quartile)			0.190	0.111						
			(0.662)	(0.400)						
law (3rd quartile)			0.054	-0.125						
			(0.175)	(-0.424)						
law (4th quartile)			0.181	-0.162						
			(0.512)	(-0.476)						
regulatory quality (2nd quartile)					-0.711	-0.500				
					(-1.531)	(-1.170)				
regulatory quality (3rd quartile)					-0.932*	-0.753*				
					(-1.921)	(-1.740)				
regulatory quality (4th quartile)					-0.871*	-0.878**				
					(-1.821)	(-2.084)				
log FDI							0.016	0.067*		
							(0.273)	(1.713)		
log trade									0.948**	0.937***
									(2.414)	(3.013)
Asia		-1.587		-1.031		-0.973		-1.594		-1.483
		(-1.465)		(-1.023)		(-0.950)		(-1.475)		(-1.410)
Latin America & Carribean		-2.992***		-2.541***		-2.519***		-2.890***		-2.763***
		(-3.208)		(-3.135)		(-3.168)		(-3.151)		(-3.204)
Middle East & North Africa		0.324		0.556		0.721		0.288		0.786
		(0.471)		(0.903)		(1.181)		(0.410)		(1.314)
_cons	-17.830***	-16.307***	-8.420*	-13.537***	-8.882*	-13.106***	-19.884***	-15.960***	-21.927***	-17.287***
	(-2.995)	(-4.082)	(-1.659)	(-4.716)	(-1.653)	(-4.565)	(-3.417)	(-4.113)	(-3.894)	(-4.412)
Number of observations	872	872	499	499	499	499	813	813	855	855
r2_o	0.036	0.144	0.048	0.201	0.031	0.188	0.040	0.143	0.039	0.167
r2_w	0.346	0.326	0.306	0.259	0.314	0.275	0.366	0.349	0.380	0.366
r2_b	0.052	0.233	0.058	0.263	0.032	0.242	0.054	0.222	0.042	0.235
time fixed effects?	YES		YES		YES		YES		YES	
Sargan-Hansen statistic		13.501		11.984		24.753		16.336		13.719
p-value		0.001		0.035		0.000		0.001		0.003

note: *** p<0.01, ** p<0.05, * p<0.1

5 Conclusions

This paper investigates the determinants of RET adoption in developing countries. We use panel data on electricity generation from renewable sources (hydropower, as well as non-hydropower) in developing countries for the 1980–2008 period. Building upon theoretical insights, we focused our attention on the respective roles of factors that are specific to the renewable energy sector and more general drivers of technology adoption.

Our estimates point to several interesting observations; in practically all specifications, the hypothesis that increasing GDP is accompanied by increasing hydro- and non-hydropower use is confirmed. The adoption of hydropower is largely dependent on local endowments. Feed-in tariffs for renewables and trade are found to have a positive influence on the adoption of non-hydropower (but not on hydropower deployment). Overall, the above results are robust to a different treatment of zero-valued observations. In contrast, the findings with regard to the other control variables are not robust.

Summarizing, some more considerations have to be done as both applied procedures for dealing with zero-valued observations involve problems: While substituting these observations by a small amount is arbitrary and lacks theoretical justification, a restriction of the sample to non-zero observations implies a sample selection problem. Thus, in a next step, we will apply alternative regressions techniques such as Poisson specifications to adequately deal with zero-valued observations of renewable electricity generation. Moreover, we will consider non-hydropower sources of renewable energy in a more aggregate manner. This will allow us to control for the specific local endowments of each non-hydro technology.

One problem with this methodology is that it does not allow to properly dealing with zero-valued observations. Hence, our results will be supplemented by Poisson regressions which can also be applied to non-negative continuous variables (Burger et al. (2009), Wooldridge (2002).

6 Appendix

Table A 1: Definition and Sources of Variables

Variable	Definition	Source
HPC	per capita electricity generation from hydropower (kwh)	EIA
NHPC	per capita electricity generation from non-hydropower (kwh)	EIA
hydropot	technically exploitable capability of hydropower	World Energy Council of Energy Resources
feed-in tariff	Dummy variable taking value 1 if feed-in policy has been enacted	REN21 (2010)
gdppc	GDP per capita in constant 2005 US$	World Development Indicators (World Bank)
rule of law	Governance indicator	Kauffman et al. (2010)
regulatory quality	Governance indicator	Kauffman et al. (2010)
trade	Trade as a percent of GDP	World Development Indicators (World Bank)
fdi	FDI net inflows, (percent of GDP)	World Development Indicators (World Bank)
enrolment rate	School enrollment, primary (percent gross)	World Development Indicators (World Bank)
completion rate	Primary completion rate, total (percent of relevant age group)	World Development Indicators (World Bank)
assets	deposit money bank assets/bank assets	Financial Structure Dataset (Beck et al. 2010)
liabilities	liquid liabilities/GDP	Financial Structure Dataset (Beck et al. 2010)
regional dummies	Asia, Europe, North Africa, Sub-Saharan Africa, Latin America and Caribbean	UNSTATS

Table A 2: Hydropower - Log-Normal Fixed Effects Specification – Including Zero-Valued Observations

	HFE1	HFE2	HFE3	HFE4	HFE5	HFE6	HFE7	HFE8	HFE9
	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t
log gdppc	1.116**	0.334**	0.462***	1.009*	0.968**	0.858***	0.337	1.137*	0.286
	(2.070)	(1.967)	(2.800)	(1.773)	(2.071)	(2.613)	(1.257)	(1.854)	(0.839)
feed-in tariff	-0.421***	-0.043	-0.041	-0.375**	-0.419***	-0.357**	-0.300*	-0.444**	-0.343**
	(-2.631)	(-0.569)	(-0.564)	(-2.345)	(-2.842)	(-2.136)	(-1.894)	(-2.511)	(-2.196)
law (2nd quartile)		-0.026							
		(-0.393)							
law (3rd quartile)		0.031							
		(0.256)							
law (4th quartile)		-0.254							
		(-1.408)							
regulatory quality (2nd quartile)			-0.113**						
			(-2.123)						
regulatory quality (3rd quartile)			-0.116						
			(-1.427)						
regulatory quality (4th quartile)			-0.024						
			(-0.168)						
log FDI				-0.003					
				(-0.155)					
log trade					0.051				
					(0.328)				
log enrolment rate						0.365			
						(0.934)			
log completion rate							0.294		
							(1.047)		
log assets								0.049	
								(0.268)	
log liabilities									0.016
									(0.144)
_cons	-5.705	0.952	-0.035	-4.837	-4.743	-5.212*	-0.925	-6.137	0.625
	(-1.376)	(0.713)	(-0.027)	(-1.107)	(-1.294)	(-1.829)	(-0.418)	(-1.178)	(0.249)
Number of observations	3,286	1,625	1,625	2,866	3,183	2,702	1,905	2,935	2,512
r2_o	0.056	0.085	0.043	0.042	0.046	0.093	0.109	0.065	0.048
r2_w	0.106	0.035	0.021	0.084	0.097	0.096	0.093	0.103	0.104
r2_b	0.047	0.086	0.039	0.048	0.043	0.049	0.069	0.047	0.048
time fixed effects?	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sargan-Hansen statistic	6.141	6.184	6.829	7.527	21.372	8.465	2.874	6.430	7.021
p-value	0.046	0.289	0.234	0.057	0.000	0.0373	0.4115	0.093	0.071

note: *** p<0.01, ** p<0.05, * p<0.1

Table A 3: Non-Hydropower - Log-Normal Fixed and Random Effects Specification II – Including Zero-Valued Observations

	NHFE6 coef/t	NHRE6 coef/t	NHFE7 coef/t	NHRE7 coef/t	NHFE8 coef/t	NHRE8 coef/t	NHFE9 coef/t	NHRE9 coef/t
log gdppc	2.499***	2.186***	2.572***	2.048***	2.006***	1.792***	0.807	1.993***
	(4.392)	(4.422)	(3.805)	(3.882)	(3.373)	(3.531)	(0.941)	(3.757)
feed-in tariff	2.141***	2.285***	1.729**	1.925***	2.213***	2.313***	1.918**	2.242***
	(3.272)	(3.504)	(2.422)	(2.725)	(3.274)	(3.468)	(2.570)	(3.176)
log enrolment rate	-0.197	-0.195						
	(-0.499)	(-0.511)						
log completion rate			0.245	0.265				
			(0.547)	(0.618)				
log assets					0.091	0.128		
					(0.528)	(0.750)		
log liabilities							0.116	0.131
							(0.688)	(0.777)
Asia		0.180		-0.078		0.177		-0.157
		(0.246)		(-0.097)		(0.243)		(-0.186)
Latin America & Carribean		-1.263		-1.145		-0.635		-1.268
		(-1.165)		(-0.983)		(-0.576)		(-0.948)
Middle East & North Africa		2.346**		2.277**		2.659**		2.139**
		(2.184)		(1.971)		(2.568)		(1.967)
Sub-Saharan Africa		-1.899***		-2.188***		-1.942***		-2.280***
		(-4.064)		(-4.028)		(-4.265)		(-4.178)
_cons	-23.166***	-21.459***	-25.687***	-22.211***	-20.650***	-19.847***	-11.688*	-20.926***
	(-5.177)	(-5.885)	(-4.900)	(-5.733)	(-4.591)	(-5.421)	(-1.777)	(-5.339)
Number of observations	2,702	2,702	1,905	1,905	2,935	2,935	2,512	2,512
r2_o	0.170	0.276	0.160	0.278	0.152	0.242	0.151	0.253
r2_w	0.159	0.158	0.130	0.129	0.136	0.135	0.181	0.137
r2_b	0.135	0.253	0.138	0.253	0.146	0.276	0.144	0.292
time fixed effects?	NO		NO		NO		YES	
Sargan-Hansen statistic		11.052		9.924		6.787		5.495
p-value		0.011		0.019		0.079		0.139

note: *** p<0.01, ** p<0.05, * p<0.1

Table A 4: Non-Hydropower - Log-Normal Fixed and Random Effects Specification II – Omission of Zero-Valued Observations

	NHFE6 coef/t	NHRE6 coef/t	NHFE7 coef/t	NHRE7 coef/t	NHFE8 coef/t	NHRE8 coef/t	NHFE9 coef/t	NHRE9 coef/t
log gdppc	2.557***	2.155***	2.721***	2.041***	2.484***	2.060***	2.514***	2.133***
	(3.314)	(4.311)	(2.720)	(3.453)	(3.351)	(4.002)	(2.909)	(3.836)
feed-in tariff	0.846*	1.020**	0.730*	0.958***	0.741	0.915**	0.934*	1.105**
	(1.876)	(2.494)	(1.878)	(2.700)	(1.606)	(2.195)	(1.801)	(2.297)
log enrolment rate	-0.070	0.038						
	(-0.066)	(0.042)						
log completion rate			-0.792	-0.094				
			(-1.014)	(-0.176)				
log assets					0.379	0.539		
					(1.050)	(1.388)		
log liabilities							0.046	0.151
							(0.264)	(1.032)
Asia		-1.625		-1.432		-1.601		-1.602
		(-1.491)		(-1.344)		(-1.506)		(-1.325)
Latin America & Carribean		-2.913***		-2.751***		-2.844***		-2.928***
		(-3.156)		(-2.875)		(-3.129)		(-2.593)
Middle East & North Africa		0.359		0.577		0.489		0.298
		(0.521)		(0.833)		(0.738)		(0.448)
_cons	-19.595**	-16.233***	-18.230**	-14.829***	-20.691***	-17.682***	-19.578***	-16.482***
	(-2.092)	(-2.726)	(-1.990)	(-3.114)	(-3.416)	(-4.209)	(-2.749)	(-3.645)
Number of observations	774	774	566	566	824	824	752	752
r2_o	0.043	0.154	0.059	0.204	0.035	0.135	0.044	0.108
r2_w	0.357	0.337	0.337	0.298	0.353	0.341	0.352	0.338
r2_b	0.060	0.243	0.076	0.285	0.055	0.236	0.046	0.185
time fixed effects?	YES		YES		YES		YES	
Sargan-Hansen statistic		14.241		12.343		12.823		9.909
p-value		0.003		0.006		0.005		0.019

note: *** p<0.01, ** p<0.05, * p<0.1

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