Access to electricity and socio-economic characteristics: panel data evidence from 31 countries

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Abstract

The case study literature on access to electricity highlighted a number of socio-economic variables linked to it. The purpose of our research is to check whether these variables also show up in panel data/cross-country regressions and to assess their relative strength. Our results support the widespread belief that electrification plans in developing countries should target rural areas and extensively rely on renewable energy sources. They should also be accompanied by measures fostering human capital accumulation and the involvement of local population. These general results need to be gauged within each country's specific context, carefully considering its own complexities. Therefore, our results complement, rather than substitute the available case study literature.

Keywords: electricity access, panel data regression, socio-economic variables, developing countries.

JEL Codes: Q01, Q29, Q39, Q42, O10, O50.

1. Introduction

Energy access is traditionally one of the central aspects of economic and social development as recently testified also by Srivastava and Sokona (2012). The present work differs from most of the available literature, reviewed below, on methodological grounds. Our purpose here is to check whether cross-country regression analysis can find support for the determinants of access to energy already highlighted by the voluminous case studies literature. This strategy has the advantage to quantify the strength of the correlations between energy access and a number of different socio-economic factors. It can therefore offer guidance to policy makers, as policy packages can be designed to insist on stronger connections, especially when resources are scarce. Weaker links, instead, could be expected to follow as the area of intervention exits its backwardness.

To the best of our knowledge, only two studies followed a similar methodological path in the past. Nanka-Bruce (2010) focused on Sub-Saharan Africa. She regressed the percentage of rural population with access to electricity on the Human Development Index, GDP per capita, the Gini Index, Foreign Direct Investment, a proxy for institutional quality, net aid inflows and urban population. The Human Development Index and urban population turned out to be positively and significantly correlated with the dependent variable, while the Gini index negatively and significantly. The other regressors were not significantly different from zero. Onyeji et al. (2012) stressed instead the role of poverty and rural population - having a negative correlation with the percentage of population with electricity access - and of funding availability and population density - with a positive correlation.[1]

[1] Other econometric studies in the field do not make use of cross-country datasets. For instance Kemmler (2007) and Bhandari and Chinmoy (2010) consider Indian household level data. Oda and Tsujita (2011) exploit a dataset regarding Indian villages.

We innovate with respect to these two seminal contributions under several respects. First we consider a panel data setting. This will help us to better treat unobserved heterogeneity, a customary advantage of panel data regressions over cross-sectional ones. In other words, our estimates are robust to the fact that we cannot observe some country specific - time invariant characteristics, such as natural resources endowment or peculiar and persistent regulatory and institutional frameworks. In addition we consider the effect of different energy sources on electricity access. This issue was widely explored in the case studies literature, stressing the importance of renewable energy generation, but not in available cross-country regressions.

The rest of this paper is structured as follows. The next section offers a brief literature review. Then we describe our data sources and definitions. The fourth section illustrates our results and robustness checks, which are then further expanded in the fifth section. Finally we conclude and we discuss policy implications.

2. Literature review

As mentioned above the object of our analysis is prominent and, therefore, the relevant literature is vast. Recently, four extensive literature reviews were offered. Javadi et al. (2013) and Bazilian et al. (2012) are critical assessments of the policies implemented in various country. Lahimer et al. (2013) focuses on institutional aspects and on the technologies households adopt to get energy access. Finally, Cook (2011) is concerned with the role of infrastructures. In what follows we briefly summarize the themes of the literature presented by the bespoken reviews, while tending, at the same time, to give more weight either to studies not included in the above surveys or to aspects of the literature they do not particularly stress.

Cook (2011), Bazilian et al. (2012), Javadi et al. (2013) and Lahimer et al. (2013) highlight a number of factors connected to energy access. Negative links exist with the remoteness of communities, low consumption in remote areas due to low income and high costs of distribution. Access to energy is instead positively connected to renewable energy generation - when feasible and often in off-grid systems (Barnes, 2011; Khennas, 2012; Buchholz and Da Silva, 2010; Oseni, 2012b; Yadoo and Cruickshank, 2012) -, the availability of human capital - also in the form of expertise for maintenance and service purposes after sale -, and the availability of funds - for example to build infrastructures and to produce manufacturing capital goods for renewable energy generation (Khennas, 2012).

Since different energy sources were not included in previous cross-country estimates we digress on them in the few following paragraphs. Developing countries are strongly dependent on fossil fuel for electricity generation. It has been highlighted how fossil sources present characteristics which may hinder access to electricity. First of all fossil fuel sources, especially oil, are characterized by highly volatile and rising prices. Thus large dependence on them can negatively affect the cost of electricity .

Moreover, as highlighted by Sokona et al. (2012) in the case of Africa, fossil fuel reserves are characterized by widely unequal distribution among regions and territories. This requires costly investments in the distribution infrastructures. Distribution costs linked to traditional fossil fuel resources and traditional power systems are further exacerbated by the fact that in many developing countries - in spite of growing tendencies towards spatial concentration and urbanization - the population and industries are still characterized by a very scattered settlement pattern (ibidem).

On the opposite renewable energy sources are generally more territorially distributed and thus they can be less costly, requiring less investments in new distribution networks. Furthermore they can also be the base for development of mini-grids and off-grids systems (e.g. Yadoo and

Cruickshank, 2012; Glemarec, 2012). As stressed by Khennas (2012, 23) these can be reliable and cost effective solutions for ensuring access to electricity to rural people.

However, concerning renewable energy sources particular attention has to be given to the kind of natural source and the characteristics of the facility. In particular, the environmental and social sustainability of large hydroelectric plants has been severely questioned by a number of studies (e.g. Finley-Brook and Thomas, 2011; Erlewein and Nüsser, 2011; Khennas, 2012). These have highlighted that in many developing countries the building of large-scale dams - often co-financed by industrialized countries through the Clean Development Mechanism - further exacerbated social and environmental local inequalities, by adversely affecting indigenous land tenure, disrupting local water-dependent agricultural systems and limiting local access to water resources. Eventually, these energy developments may result in forms of "hydrologic colonialism" (Finley-Brook and Thomas, 2011), namely the process through which source territories - often rural underdeveloped areas - are burdened with economic, environmental and social costs, while benefits are exported elsewhere – often to urban industrialized centers.

Going back to general issues, the direction of causality is often difficult to define. Electricity access, for instance, can improve health, as hospitals can work at night too. It can also improve education, by extending the time for studying, and, therefore, reduce inequality. One further implication of greater energy access is welfare improvement as a consequence of a more amenable life, once the time devoted to domestic activities decreases and spare time increases. As a consequence, migration to urban areas - which often regards young productive people - can decrease. This, together with greater availability of energy inputs for local firms (Kooijman-van Dijk and Clancy, 2010; Kirubi et al., 2009) and more time for market activities, can increase productivity and therefore income. Remarkably, Kanagawa and Nakata (2008) used the electrification rate as an explanatory variable for the literacy rate of rural areas in the Indian state of Assam.

On the other hand, relatively high income is a condition for high electricity demand, that can assure the profitability of its distribution to a given area. At the same time the availability of funds and human capital can foster electricity access, the former ones to buy generation devices and the latter one to install and maintain them. In addition, energy access innovations can work as product innovations rising labor productivity (Agbemabiese et al., 2012). In general, it could be that all these aspects are different dimensions of a poverty trap in which an area might be locked in. Not surprisingly Brew-Hammond (2010) referred to similar situations as characterized by vicious circles.

The quality of regulation and institutions do play a role as well. In particular Yadoo and Cruickshank (2010) stress that recent privatization and liberalization processes have increased rents extracted by utilities from consumers and they have not spurred energy access[2]. They also review various models for electricity delivery in developing countries - concessionary models, dealership approaches, strengthening of small and medium sized energy businesses, cooperative-driven delivery approaches - concluding that the last one is superior to the others[3]. Also Mawhood and Gross (2014) focus on the importance of good institutions. In their view, the Senegalese Rural Electrification Plan found obstacles in a number of institutional and political barriers, such as inconsistent ministerial and political support, limited institutional capacity, and protracted consultations. Similar situations are rather widespread in underdeveloped countries (Karekezi and Kimani, 2004). In sum, barriers to rural electrification can be economic, legal, financial and institutional (Javadi et al., 2013). Proper institutions are also a condition for innovations in energy access (Agbemabiese et al., 2012) and for public-private partnerships, important to raise funds to extend energy access (Chaurey et al., 2012). It is worth recalling that proper institutions and policy

[2] Goldemberg et al. (2004) make the same point on analyzing the 1990s restructuring process of the Brazilian electricity sector. On this issue also see Sokona et al. (2012).

[3] The importance of cooperatives for rural electrification was also stressed by Barnes (2011) regarding the US, Bangladesh, Costa Rica and the Philippines.

designs are often hampered by vested interests and successful countries often applied a bottom-up approach involving local citizens in electrification plans (Rehman et al., 2012; Gómez and Silveira, 2010; Bhattacharyya and Ohiare, 2012; Davidson and Mwakasonda, 2004). The next section moves to consider our data sources and definitions.

3. Sources and definitions of baseline data

We collected data on a number of different variables. Our dependent variable is the percentage of population that has access to electricity. We try to correlate it, over various model specifications, with the number of borrowers from commercial banks (per 1,000 adults); the percentage of total electricity production deriving from fossil fuels, hydroelectric sources, other renewable sources respectively; GDP per head in current PPP US dollars; the percentage of rural population or, alternatively, that of urban population; the percentage of GDP accruing to natural resources rents; the completion rate in lower secondary schools.

Our data come from the 2014 edition of the World Development Indicators (WDI) by the World Bank. Our sample include 31 countries namely Algeria, Bangladesh, Bolivia, Brunei Darussalam, Chile, Colombia, Republic of Congo, Costa Rica, Dominican Republic, Ecuador, Ghana, Guatemala, Indonesia, Israel, Lebanon, Malaysia, Mongolia, Mozambique, Namibia, Nepal, Pakistan, Panama, Paraguay, Peru, Qatar, Saudi Arabia, Tunisia, Uruguay, Venezuela, the Republic of Yemen, Zambia. Data on the percentage of population that has access to electricity is only available for the years 2010 and 2011, so we limit our analysis to those years. We consider the number of borrowers from commercial banks (per 1,000 adults) as a measure of access to the credit market. As stressed above, either different energy sources or the distribution of the population in cities or in the countryside can have different impact on access to electricity, so we control for them.

The rents from natural resources as a percentage of GDP are considered because a country with a greater endowment of natural resources could in principle provide electricity to its population with more ease, unless income distribution and vested interests withered this link. Therefore, this variable could help to capture the paradox that many countries have a low performance regarding access to electricity in spite of their large endowment of energy sources, especially oil - as it happens in many African countries (Khennas, 2012).

The completion rate in lower secondary schools is a measure of human capital. We give weight to secondary schooling on the footsteps of Mankiw et al. (1992). GDP per head is a customary measure of the flow of economic resources accruing to individuals over a year.

It would be interesting to consider also the effect of inequality on our dependent variable. However, data for the GINI index is not available for many countries in WDI. It would be possible to supplement them with data from the UNU-WIDER dataset. Unfortunately, they often refer to years before 2010. In principle, it would be possible to insert it into our model, but this would produce a variable that does not vary over time. Since we will use a panel data model, the implied data transformation in the fixed effects estimator would wipe this variable out, making the model not strictly comparable to the random effects one to be contrasted with by means of the Hausman test.[4] In fact, one of the advantages of panel data methods is to be robust to time-invariant unobserved heterogeneity (Baltagi, 2003) and inequality measures would turn out to be so given their paucity of data. Note that we also tried to include in our estimates the poverty headcount ratio at $2 a day (PPP). However, the number of observations dropped so much to prevent obtaining any result.

[4] A possible strategy would be to consider only cross-sectional estimates. This is what we do in Appendix B. In this context, the GINI index has a negative link with electricity access. One further strategy would be to add the GINI index as a further control in baseline random effects estimates after conducting the Hausman test. In this case, the GINI index would have a coefficient of -0.66 with a p-value of 0.001. The standardized coefficient would be equal to -0.24. We do not devote more space to these estimates because GINI indexes refers to different years than 2010 and 2011.

Table 1 sets out descriptive statistics about our variables of reference. There is a good variability in the data, but in some cases it might even appear excessive. So special care will be devoted to the possible effect of outliers on our results, and we will always make use of estimators robust to heteroscedasticity. One further consideration is that variables tend to have different scales. So when finally commenting the magnitude of the coefficients of our preferred variables we will make use of standardized coefficients.

Correlations between regressors tend to be small (Table A1), avoiding risks of collinearity. There is one remarkable exception to this pattern: the correlation between the number of borrowers from commercial banks per 1,000 adults and the percentage of either urban or rural population. We will therefore carefully consider results regarding these variables. Further note that it is not possible to include in the same sample the percentage of total electricity production deriving from fossil fuels, hydroelectric sources, and other renewable sources. This is because they sum to one hundred in 91% of our sample. For similar reasons, one cannot include in the same model both the percentages of rural and urban population. We now move on to illustrate our results.

4. Results

We try very many different specifications as set out in Table 2. Each specification is marked by a number in the first row of the Table. Note that we always consider contemporary values for the dependent and the independent variables. In principle, it would be possible to use either lagged values of the independent variables or past moving averages of theirs in an effort to capture causal effects. However, given the issues surrounding the direction of causality highlighted above, these strategies might not be able to really identify causal nexuses. This appears especially likely in poverty traps where economic variables tend to display a high degree of persistence, whereby, for instance, past low electricity access may underlie both current low electricity access and current low GDP per capita. Therefore, we here focus on correlations only.

In Specification 1 we start regressing the share of population with access to electricity on the number of borrowers from commercial banks per 1,000 adults, the percentage of electricity generated from renewable sources (excluding hydroelectric power), GDP per capita, the percentage of rural population, total natural resources rents, the lower secondary completion rate, and a constant.

We adopt a random effects estimator after running a Hausman test. This test checks whether the random and the fixed effects estimators are close. If they are not, the latter will be preferred to the former as it is unbiased. If, as in our case, they are close, then the former should be preferred as it is more efficient.

As clear in Specification 1 - our baseline model - the dependent variable positively and significantly correlates with electricity generation form renewable sources, the 2011 dummy and our human capital variable. Negative and significant correlation shows instead up for the percentage of rural population and total natural resources rents. Regarding this last result, it would seem that yields from natural endowments do not tend to be distributed to the poor (especially in the basic form of electricity access). Other regressors are not significant.

Once switching to fossil energy sources and hydroelectric power, the effect of electricity generation turns negative (Specification 2), as a possible consequence that these kinds of sources are generally used to supply on-grid urban centers and not off-grid rural communities - though having been showed to have in principle the potential to enhance electricity access (Kirubi et al., 2009). In Specification 3, we substitute the percentage of urban population for the rural one, the relevant coefficient just changes sign. Once going back to renewable electricity generation as our energy variable, the implications arising from the new results are very similar to those arising from our baseline model.

In Specification 4, we take a number of different steps. It might be the case that our results are driven by outliers, so we first run year specific regressions for our baseline model and we next plot the leverage of each observation against the square of the relevant residual (Figures 1 and 2).[5] On the basis of the plots, we exclude from the sample the 2010 observations of Brunei, Guatemala, Israel, Congo, Mongolia, Nepal, Zambia, Namibia, and Algeria. For 2011, we further exclude observations of Qatar, Guatemala, Republic of Congo, Brunei Darussalam, Mozambique and Paraguay. Our baseline results hardly change (see also Specification 5).

In column 6, we make use of standardized coefficients in order to understand which factors might be stronger than others. The percentage of rural population and human capital have the largest coefficients, followed by distributive factors and renewable energy generation. Financial development display low significance in all our models.

However, before giving a final assessment regarding coefficient size and significance, one has to bear in mind the above mentioned problem of high correlation among some explanatory variables. Belsley et al. (1980, 194-199) propose to insert restrictions as a remedy to this problem. In order to do so, on the basis of inspection of the results in column 6 of Table 2, we test the validity of four restrictions: i) ten times the coefficient of the number of borrowers from commercial banks per 1,000 adults is equal to the coefficient of the share of electricity production from renewable sources, excluding hydroelectric power; ii) the coefficient of the share of electricity production from renewable sources, excluding hydroelectric power, is equal to the

[5] An observation has leverage when it tends to have values far from the mean.

opposite of rents accruing from natural resources as percentage of GDP; iii) ten times the coefficient of GDP per capita in PPP current international dollars is equal to the opposite of the coefficient of the share of rural population; iv) ten times the coefficient of GDP per capita in PPP current international dollars is equal to the coefficient of the completion rate of lower secondary schools. The test, distributed as a χ^2 with 4 degrees of freedom, returns a p-value of 0.97. This approach also permits to take into account the presumption that a greater access to the credit market should foster access to electricity. On these grounds we proceed with a restricted estimation whose results are set out in column 7 of Table 2.

Our restricted results would point to several important implications. All our variables enhance access to electricity with the exception of the percentage of rural population and of rent accruing from natural resources. Three groups of variables can be distinguished on the basis of standardized coefficients: i) the variables with the smallest effect on access to electricity, namely access to the credit market and GDP per capita; ii) the variables with an intermediate effect, namely renewable energy generation and rents from natural resources; iii) the variables with the strongest effect, namely the percentage of rural population and human capital.

5. Robustness checks

We conduct two kinds of further robustness checks. First we change our indicator for the availability of funds and we add more controls. In the second place, we add to our baseline estimates some scores of institutional quality.

5.1 Further specifications

We test the robustness of our results by changing the specification of our baseline model on the basis of results available in the literature. The descriptive statistics of our additional controls are set out in Table 3.

The data regarding gross domestic savings (% of GDP) and population density (people per square km of land area) were obtained from the 2014 edition of WDI. Data for the total net installed capacity of electric power plants (including public and self-producers) were downloaded from the UN data portal (http://data.un.org). We consider this variable as Shrestha et al. (2004) found that it can be a constraint for electricity distribution. Finally data for energy related gross fixed capital formation in constant 2000 millions of US dollars were obtained by extrapolating the series available in Bazilian et al. (2011).

We directly standardize our variables for sake of brevity and to obtain comparable coefficients. We first substitute the number of borrowers from commercial banks per 1,000 adults with energy related gross fixed capital formation. As it is possible to see in Column 1 of Table 4 results hardly change with respect to baseline ones. Next, we maintain all the restrictions imposed in the previous section, with the exception of the first one assuming that two times the coefficient of energy related gross fixed capital formation is equal to the coefficient of the share of electricity production from renewable sources, excluding hydroelectric power. The null that the restrictions suit the data is not rejected by a χ^2 with 4 degrees of freedom, returning a p-value of 0.11. In the restricted estimates, the availability of funds acquires some more importance as the relevant coefficient is about eight times larger than the comparable one in the seventh column of Table 2.

In our next robustness check, we do not only change the indicator for the availability of funds, shifting to the ratio of gross domestic savings to GDP, but we also add the total net installed capacity to generate electricity and the population density as further regressors. The number of observations drops to 29. The countries included in the sample are now Bolivia, Colombia, Congo (Rep.), Costa Rica, Ecuador, Guatemala, Israel, Mongolia, Namibia, Nepal, Pakistan, Panama, Paraguay, Qatar, Saudi Arabia, Uruguay, Yemen (Rep.), and Zambia.

Nonetheless, baseline results are confirmed. For this model we impose the following restrictions: i) the coefficient of gross domestic savings as percentage of GDP is equal to the one of the share of electricity production from renewable sources, excluding hydroelectric power; ii) the coefficient of the share of electricity production from renewable sources, excluding hydroelectric power, is equal to the opposite of rents accruing from natural resources as percentage of GDP; iii) ten times the coefficient of GDP per capita in PPP current international dollars is equal to the opposite of the coefficient of the share of rural population; iv) ten times the coefficient of GDP per capita in PPP current international dollars is equal to the coefficient of the completion rate of lower secondary schools; v) the coefficient of GDP per capita in PPP current international dollars is equal to the coefficient of population density; vi) the coefficient of GDP per capita in PPP current international dollars is equal to the coefficient of total net installed electricity generation capacity times one half. The test, distributed as a χ^2 with 6 degrees of freedom, returns a p-value of 0.62.

The main difference with respect to previous results is that the financial availability indicator increases further reaching a similar value to that of the share of renewable electricity generation. Electricity generation capacity and population density are positively connected to access to electricity but their coefficients tend to be smaller than those of the other regressors.

5.2 Institutional indexes

We further insert in our baseline model some indicators regarding the quality of the institutions of a given country, namely the CPIA rating for transparency, accountability, and corruption in the public sector, the CPIA rating for efficiency of revenue mobilization, and the CPIA rating for property rights and rule-based governance. The CPIA acronym stays for Country Policy and Institutional Assessment. The data source is the 2014 edition of WDI.

These scores are given on a one to six scale, with one being the lowest score and six the highest. Note that, in our sample, the minimum and the maximum scores are 2.5 and 3 for the first and third indicators and 3 and 4 for the second one.

The number of observations drops to 18, including the following countries: Colombia, Congo (Rep.), Dominican Republic, Ecuador, Indonesia, Mongolia, Pakistan, Panama and Peru. We consider each indicator one at a time due to the small number of observations. We directly focus on the results of the institutional indicators for sake of brevity and because our baseline results are by and large unaltered.

All the three indicators are positively and significantly correlated with access to electricity either at or close to the 1 per cent level. The first one has a coefficient of 13.73, the second one of 19.98 and the third one of 8.32. Therefore, the quality of a country's institutions and policies can be sizably correlated with electricity access.

6. Conclusions and policy implications

Energy poverty is a multidimensional problem, which requires multidimensional policies as envisaged by Brew-Hammond (2010) and Andrade et al. (2011) for instance. Our results can offer guidance to these efforts. Note that the role of institutions will not be the main focus of the discussion below given the small sample problems emerged in the above relevant section.

To sum up, the energy literature highlighted some factors that have a link with access to energy mainly by making use of case studies. Our research questions were: are these factors so strong to show up even in cross-country regressions? Is this strong equal for all of them?

We highlighted that the connections of access to electricity with socio-economic variables have strength enough to appear in panel data cross-country regressions and that this strength is different for different variables. The strongest links are the negative one with the percentage of rural population and the positive one with human capital. They are followed by electricity production by renewable energy sources - with a positive sign - and rents from total natural resources - with a negative one. GDP per capita, electricity net installed capacity and population density have minor positive roles. The strength of the link with the availability of funding varies depending on the adopted indicator. It is weaker with a measure of access to the credit market, as the number of borrowers per 1,000 inhabitants, and stronger with gross domestic savings as percentage of GDP. This could be the sign that the credit market, due to its imperfections (Stiglitz, 1993), might not be the best institution to channel funding to enhance electricity access. Public intervention might instead be better in mobilizing one country's available savings for this purpose. Also institutional quality has a role, though we could show it for a limited portion of our sample, given data availability.

These results support the widespread belief in the case studies literature that electrification plans in developing countries should target rural areas and exploit renewable energy sources. They should also be supplemented by interventions fostering the accumulation of human capital and measures to involve local population in order to improve one country's institutional and policy frameworks and overcome possible pressures from vested interests.

These conclusions need some qualifications, though, as our approach has a number of limitations. Given the available data, one has to restrict the definition of access to energy to access to electricity (similarly not only to the econometric studies mentioned in the Introduction but also to a wide number of previous case studies like, among many others, Thom, 2000; Oseni, 2012a; Ying, 2006; Nouni et al., 2008 and 2009; Mainali and Silveira, 2013).[6] So we have to bypass all important definition and measurement issues concerning, for instance, the definition of energy

[6] See other examples in Lahimer et al. (2013).

poverty, the availability of other forms of energy, their quality, physical deliverability, reliability, timeliness and affordability. We do not either consider the affordability of appliances and the issue whether households prefer other energy sources than electricity (Thom, 2000; Srivastava et al., 2012; Sokona et al., 2012; Hailu, 2012; Bhanot and Jha, 2012; Winkler et al., 2011; Giannini Pereira et al., 2011a and 2011b; Bhattacharyya, 2006). Nonetheless, focusing only on electricity access has an interest in itself given the importance that it has generally played in the shaping and functioning of modern economies and societies (Smil, 1994).

One further limitation is that we cannot differentiate in detail between various renewable energy sources - and, therefore, we cannot consider small scale hydro power as different than large hydro power for instance (on the importance of this distinction see, among others, Lahimer et al., 2013, Mainali and Silveira, 2013, and Gurung et al., 2011). In addition, we cannot dissect all the subtleties of the financing issues for electrification in developing countries (Bhattacharyya, 2013; Gujba et al., 2012; Bose et al., 2012; Glemarec, 2012; Mainali and Silveira, 2011), though we estimated models including different funding variables.

Therefore, our results are rather a complement, than a substitute for existing contributions in the literature. We can offer a starting point for policy makers willing to extend electricity access in their country, though keeping in mind that general results, as ours, need to be gauged within each country specific context, carefully considering its own complexities (Sokona et al., 2012; Davidson and Mwakasonda, 2004; Gómez and Silveira, 2012). All the more that the paucity of cross-country data availability not only often requires the estimation of restricted models as ours, but it also prevents the adoption of heterogeneous panel estimators, which could offer country specific econometric evidence and guidance (Baltagi, 2003).

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Table 1 - Descriptive statistics of variables under study

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Access to electricity (% of population)	52	81.99	24.14	15.00	99.90
Borrowers from commercial banks (per 1,000 adults)	52	196.90	167.15	7.43	885.37
Electricity production from renewable sources, excluding hydro power (%)	52	2.66	6.41	0.00	29.60
Electricity produced from fossil fuels (% of total electricity production)	52	57.06	36.39	0.00	100.00
Electricity production from hydroelectric sources (% of total)	52	38.79	35.85	0.00	100.00
GDP per capita, PPP (current international $)	52	15887.55	22261.30	867.57	133733.90
Rural population (% of total population)	52	35.63	19.93	1.23	83.34
Total natural resources rents (% of GDP)	52	17.15	17.30	0.00	69.98
Lower secondary completion rate, total	52	70.30	23.27	13.40	118.15
Urban population (% of total)	52	64.37	19.93	16.66	98.77
2011 dummy	52	0.44	0.50	0.00	1.00

Table 2 - Regression results. Dependent variable: Access to electricity (% of population), 2010-2011. Method: random effects model with heterokedasticity robust standard errors

Model	**1**	**2**	**3**	**4**	**5**	**Standardized Coefficients**	**Restricted Standardized Coeff.**
Borrowers from commercial banks (per 1,000 adults)	-0.0031	-0.0004	-0.0004	-0.0031	-0.0425	-0.0216	0.0181
p-value	0.7430	0.9680	0.9680	0.7430	0.1030	-	0.000
Electricity production from renewable sources, excluding hydro power (%)	0.6722	-	-	0.6722	0.7624	0.1786	0.1812
p-value	0.0010	-	-	0.0010	0.0330	-	0.000
Electricity produced from fossil fuels (% of total electricity production)	-	-0.5785	-0.5785	-	-	-	-
p-value	-	0.0000	0.0000	-	-	-	-
Electricity production from hydroelectric sources (% of total)	-	-0.6018	-0.6018	-	-	-	-
p-value	-	0.0010	0.0010	-	-	-	-
GDP per capita, PPP (current international $)	0.0001	0.0000	0.0000	0.0001	0.0002	0.0498	0.0450
p-value	0.3210	0.6930	0.6930	0.3210	0.1350	-	0.000
Rural population (% of total population)	-0.5676	-0.5622	-	-	-0.6773	-0.4686	-0.4503
p-value	0.0010	0.0030	-	-	0.0000	-	0.000
Urban population (% of total)	-	-	0.5622	0.5676	-	-	-
p-value	-	-	0.0030	0.0010	-	-	-
Total natural resources rents (% of GDP)	-0.2702	-0.3223	-0.3223	-0.2702	-0.3182	-0.1936	-0.1812
p-value	0.0080	0.0010	0.0010	0.0080	0.0240	-	0.000
2011 dummy	1.6332	1.6830	1.6830	1.6332	2.5522	0.0677	0.0645
p-value	0.0420	0.0430	0.0430	0.0420	0.0380	-	0.033
Lower secondary completion rate, total	0.4779	0.4572	0.4572	0.4779	0.4945	0.4607	0.4503
p-value	0.0010	0.0020	0.0020	0.0010	0.0080	-	0.000
Constant	69.8179	130.0358	73.8204	13.0590	79.6239	-0.0576	-.057156
p-value	0.0000	0.0000	0.0000	0.2680	0.0000	-	0.537
Observations	52	52	52	52	37	52	52
Hausman test (p-value)	0.2000	0.2700	-	-	-	-	-

Table 3 - Descriptive statistics of additional controls for robustness checks

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Energy related gross fixed capital formation	52	1577.38	2749.69	11.50	16665.40
Gross domestic savings (% of GDP)	29	13.40	27.94	-66.00	85.37
Population density (people per sq. km of land area)	52	195.93	257.01	10.73	1131.94
Electricity - total net installed capacity of electric power plants, public and self-producers	52	9661.88	11465.72	467.00	46374.00

Table 4 - Regression results. Dependent variable: Access to electricity (% of population), 2010-2011. Method: random effects model with heteroskedasticity robust standard errors

Model	1	2	3	4
Energy related gross fixed capital formation	-0.0984	0.0826	-	-
p-value	0.2670	0.0000	-	-
Gross domestic savings (% of GDP)	-	-	0.2157	0.2097
p-value	-	-	0.0440	0.0000
Electricity production from renewable sources, excluding hydro (%)	0.1739	0.1652	0.2375	0.2097
p-value	0.0010	0.0000	0.0000	0.0000
GDP per capita, PPP (current international $)	0.1445	0.0438	0.0655	0.0492
p-value	0.1720	0.0000	0.3060	0.0000
Rural population (% of total population)	-0.4440	-0.4378	-0.3455	-0.4921
p-value	0.0020	0.0000	0.0060	0.0000
Total natural resources rents (% of GDP)	-0.1958	-0.1652	-0.2337	-0.2097
p-value	0.0070	0.0000	0.0090	0.0000
Lower secondary completion rate, total	0.4573	0.4378	0.6357	0.4921
p-value	0.0010	0.0000	0.0000	0.0000
Electricity - total net installed capacity of electric power plants	-	-	0.1378	0.0984
p-value	-	-	0.4340	0.0000
Population density (people per sq. km of land area)	-	-	0.1609	0.0492
p-value	-	-	0.6330	0.0000
2011 dummy	0.0696	0.0596	0.0671	0.0613
p-value	0.0320	0.0530	0.0440	0.0140
Constant	-0.0616	-0.0575	-0.0071	-0.0368
p-value	0.5210	0.5410	0.9590	0.7430
Observations	52	52	29	29

Note: variables are standardized. Estimates in columns 2 and 4 are restricted ones. For details on the restrictions see the body of the text in the "Robustness checks - Further specifications" section.

Figure 1 - Leverage - squared residuals for the year 2010

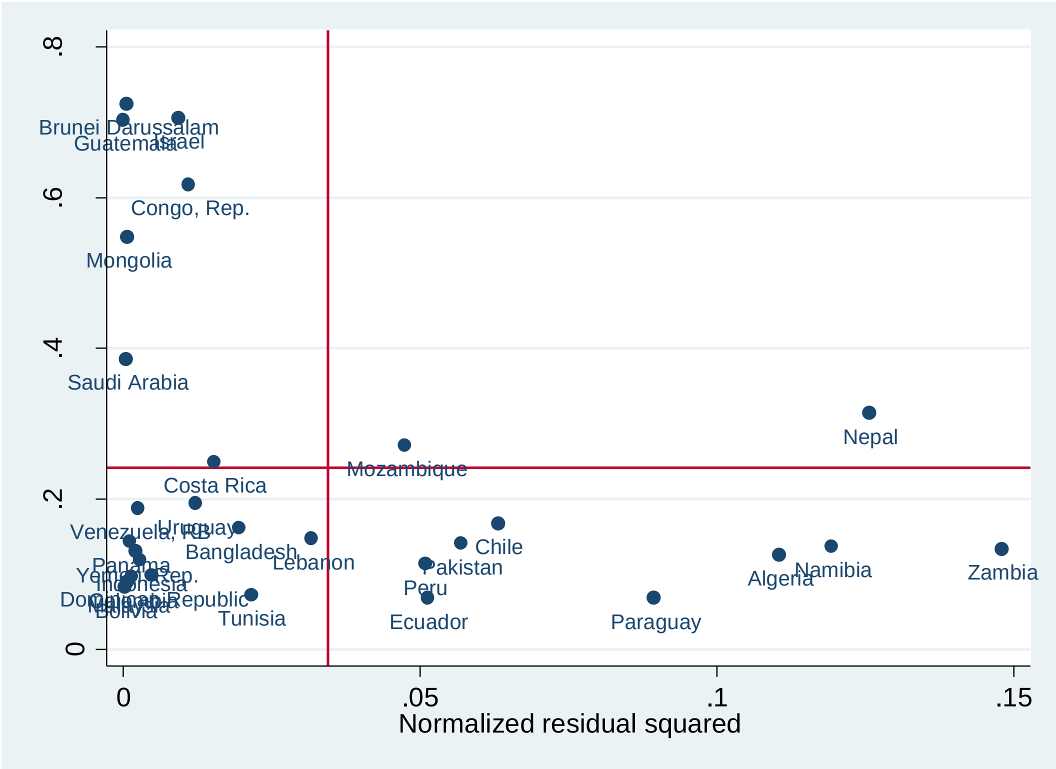
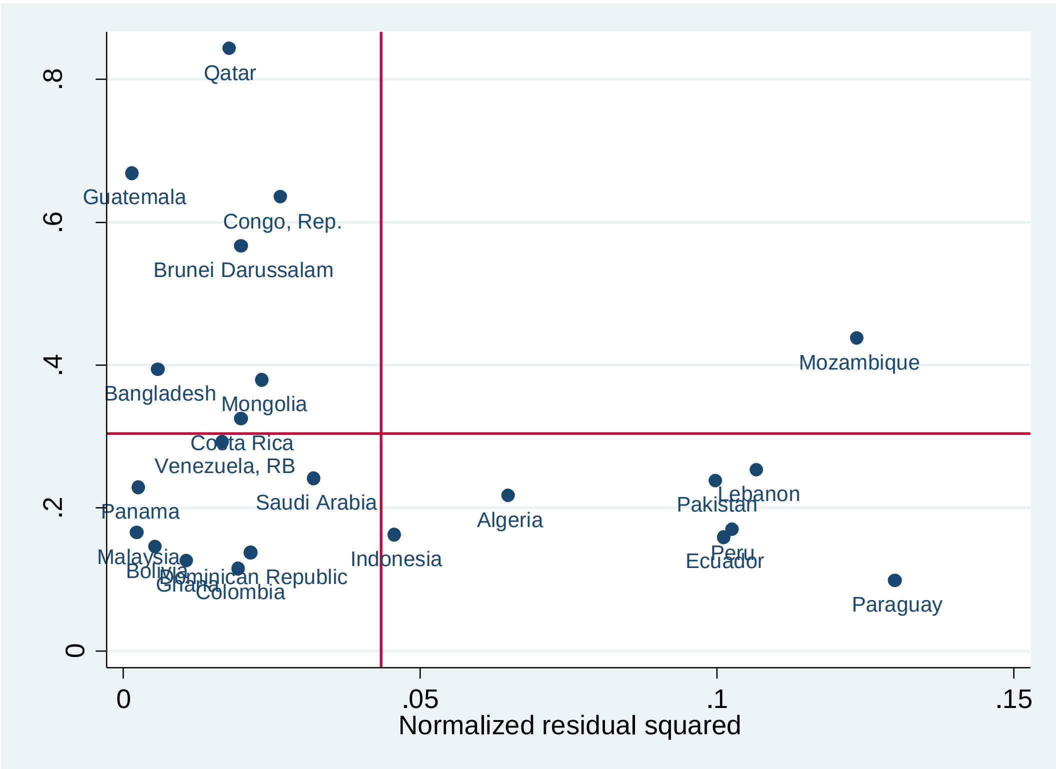


Figure 2 - Leverage - squared residuals for the year 2011



Appendix A

Table A1- Correlation matrix of baseline data

		a.	b.	c.	d.	e.	f.	g.	h.	i.	l.
a.	Borrowers from commercial banks (per 1,000 adults)	1									
b.	Electricity production from hydroelectric sources (% of total)	-0.3218	1								
c.	Electricity produced from fossil fuels (% of total electricity production)	0.2505	-0.8746	1							
d.	Electricity production from renewable sources, excluding hydroelectric (%)	0.1706	-0.0424	-0.1962	1						
e.	GDP per capita, PPP (current international $)	0.4923	-0.3218	0.1951	0.123	1					
f.	Rural population (% of total population)	-0.5984	0.3093	-0.151	-0.1693	-0.6523	1				
g.	Urban population (% of total)	0.5984	-0.3093	0.151	0.1693	0.6523	-1	1			
h.	Total natural resources rents (% of GDP)	-0.2417	0.0052	0.1537	-0.3271	0.0181	0.0821	-0.0821	1		
i.	Lower secondary completion rate, total	0.451	-0.1675	0.0427	0.0634	0.3882	-0.4328	0.4328	-0.2735	1	
l.	Access to electricity (% of population)	0.5822	-0.4297	0.3828	0.057	0.4674	-0.6646	0.6646	0.037	0.8248	1

Appendix B: Cross-sectional based evidence on access to electricity in 41 countries

B.1 Data: sources and definitions

We collected data on a number of different variables from various sources. Our dependent variable is the percentage of population that has access to electricity. We try to explain it over various model specifications as a function of the ratio between domestic credit to the private sector over GDP; the percentage of total electricity production deriving from fossil fuels, hydroelectric sources, other renewable sources respectively; GDP per head in current US dollars; the Gini index; the percentage of rural population or, alternatively, that of urban population; the percentage of GDP accruing to natural resources rents; either the total years of schooling or the years of secondary schooling.

Most of our data come from the 2013 edition of the WDI. Our sample includes 41 countries, as listed in Table B3. In the 2013 edition of WDI data on the percentage of population that has access to electricity were only available for the year 2009, so we limit our analysis to that year.[7] The ratio between domestic credit (to the private sector) over GDP is customarily used as an indicator of financial development in very many different studies (King and Levine, 1993; Beck, Levine and Loayza, 2000; Beck et al., 2007; Vaona, 2008 among others). As stressed above, either different energy sources or the respective distribution of the population in cities and in the countryside can have different impact on access to electricity, so we control for them. The GINI index and GDP per head are well known measures of inequality and productivity respectively. The reasons to include the rents from natural resources as a percentage of GDP are discussed in the body of the text. The total years of schooling and the years of secondary schooling are two well known measures of human capital. They have been extensively used in the empirical economics

[7] Electricity access data for the year 2009 disappeared in the 2014 edition of WDI.

literature (see for instance Beck et al., 2007). Specifically we give more weight to secondary schooling on the footsteps of Mankiw et al. (1992).

Data for the GINI index is not available for many countries in WDI so we supplement them with data from the UNU-WIDER dataset. Unfortunately, they often refer to previous years than 2009. We give details of the year of reference in Table B3. Though we do not consider this variable in all our model specification, we do not drop it because inequality is well known to be a persistent phenomenon (see for instance UNCDF, 2013; OECD, 2011). Data for the years of schooling come from the Barro and Lee dataset (Barro and Lee, 2013). We also tried to use a number of other different variables as explanatory factors. However, they always drastically reduced the sample, undermining the reliability of results[8].

[8] A list includes the CPIA rating of the environmental sustainability of policy and institutions; CPIA property rights and rule-based governance rating; CPIA quality of public administration rating; CPIA transparency, accountability, and corruption in the public sector rating; literacy rate, adult total (% of people aged 15 and above); primary completion rate, total (% of relevant age group); income share held by lowest 10%; income share held by lowest 20%; private investment in energy structures as share of GDP; borrowers from commercial banks in proportion to those in Israel; internally displaced persons (as % of total population); presence of peace keepers (number of troops, police, and military observers as % of total population); political rights rating by the House of Freedom; civil rights rating by the House of Freedom; status attributed to the country by the House of Freedom; the global expenditure in R&D over GDP and per person.

Table B1 sets out descriptive statistics about our variables of reference[9]. Given the variability in the data, we will carefully consider the possible effects of outliers on our results and we will always make use of estimators robust to heteroscedasticity. As in the main body of the text, we will use standardized coefficients to overcome the issue of the different scales of the variables involved in our estimates. Correlations between regressors tend to be small (Table A4), avoiding risks of collinearity. There is one unique exception to this pattern: the correlation between the percentage of electricity produced from fossil fuels and the GINI index. This a first sign of the possible effect of outliers in our study: once dropping Namibia from the sample the correlation drastically falls to -0.49. We will nonetheless avoid using these variables in the same specification. Further note that it is not possible to include in the same sample the percentage of total electricity production deriving from fossil fuels, hydroelectric sources, other renewable sources respectively. This is because they always sum to one hundred in our sample. For the same reason, one cannot include in the same model both the percentages of rural and urban population. We now move to illustrate our results.

B.2 Results

We try very many different specifications as set out in Table B2. Each specification is marked by a number in the first row of the Table. The second column of Table B3 details in which of our various specification each country is included.

In Specification 1 we start regressing the share of population with access to electricity on domestic credit to the private sector over GDP, the percentage of rural population, the percentage of electricity generated from fossil fuels and hydro power, plus a constant. As it appears clear our

[9] We have very many different specifications so we chose to show descriptive statistics for the sample used in the specifications including the greatest number of observations.

dependent variable positively correlates with our human capital variable and negatively with the percentage of rural population and electricity generated from fossil fuels and hydropower. Other regressors are not significant. The R^2 is high.

Once switching to renewable sources (excluding hydropower), the effect of electricity generation turns positive (Specification 2). In Specification 3, we add the Gini index and two continental dummies as well. The greater is inequality and the less access to electricity there is in a country. Continental dummies do not turn out to be significant, downplaying average differences between Africa, Asia and Latin America in electricity access.

In Specification 4, we take a number of different steps. First, we switch the attention from rural population to urban population. Second, we insert GDP per head in 2008. We chose this year to limit possible simultaneity biases. However, playing with different years (such as either 2007 or 2009) would not alter our results. Third, we omit Israel as it had by large the greatest GDP pear head.[10] The percentage of urban population is significant and its sign is as expected. The insignificance of GDP per head sheds, in our view, further light on the insignificance of natural resources and on the negative sign of the Gini index. They all stress the importance of distributive concerns. Productivity benefits and yields from natural endowments do not tend to be distributed to the poor (especially in the basic form of electricity access). It might be the case that our results are driven by outliers, so we plot the leverage of each observation against the square of the relevant residual (Figure B1).[11] On the basis of the plot, we further exclude from the sample Namibia, Botswana, Egypt and Panama. Our results are unaffected (Specification 5). Note that financial development now turns positive and significant. Also note that the R^2 of the model

[10] Leaving out also Qatar and inserting continent dummies would not alter our results.

[11] To produce Figure 1 we also included in the model continent dummies.

reaches 90%. The adjusted-R^2 produced by a regression without robust standard error would be 0.86. Our model, therefore, explains a good deal of variability in the dependent variable.

The effect of human capital is unaltered once considering total years of schooling instead those pertaining to secondary schools only and once switching back to rural population from the urban one (Specification 6). Finally, Specification 7 checks whether our result regarding electricity generation from renewable sources also holds when considering only countries with a negative energy balance. In general, splitting the sample would not produce significant regressors, most probably due to small sample problems.[12] We overcome this problem by interacting our renewable electricity variable with a dummy for the countries with a negative energy balance, which are listed in Table B3. Comparing columns 5 and 7 in Table B2 shows that our results are robust.

In conclusion, a cross-sectional approach yields similar results to the panel one adopted in the main body of the text.

[12] Also looking for nonlinear effects inserting powers of the independent variables would return insignificant coefficients, possibly for the same reason.

Table B1 - Descriptive statistics of variables under study

Variable	Obs	Mean	Std. Dev.	Min	Max
Access to electricity (% of population)	41	72.53	29.63	11.10	99.70
Domestic credit to private sector (% of GDP)	41	32.24	19.61	4.92	93.55
Electricity produced from fossil fuels (% of total electricity production)	41	58.97	34.58	0.00	100.00
Electricity production from hydroelectric sources (% of total)	41	37.78	34.11	0.00	100.00
Electricity production from renewable sources, excluding hydroelectric (%)	41	3.25	7.31	0.00	30.34
GDP per head in 2008 (current US$)	39	3954.07	6388.54	101.10	31214.36
GINI index	34	45.52	8.23	31.20	73.90
Rural population (% of total population)	41	43.66	21.25	1.59	86.82
Total natural resources rents (% of GDP)	41	10.90	13.33	0.15	55.98
Urban population (% of total)	41	56.34	21.25	13.18	98.41
Years of Schooling	41	6.84	2.15	1.24	11.28
Years of Secondary Schooling	41	4.46	1.26	1.07	6.60

Table B2 - Regression results. Dependent variable: Access to electricity (% of population), 2009. Method: OLS with robust standard errors

Model specification	1	2	3	4	5	6	7	8
Observations	41	41	34	31	27	41	27	27
R-squared	0.67	0.61	0.79	0.80	0.90	0.57		-
Domestic credit to private sector (% of GDP)	0.18	0.26	0.25	0.37	0.48***	0.31	0.48***	**0.25**
p-value	0.32	0.20	0.21	0.13	0.00	0.14	0.00	
Years of Secondary Schooling	11.47***	13.69***	11.84***	12.38***	14.23***	-	14.09***	**0.48**
p-value	0.00	0.00	0.00	0.00	0.00	-	0.00	-
Years of Schooling	-	-	-	-	-	5.02**	-	-
p-value	-	-	-	-	-	0.01	-	-
Rural population (% of total population)	-0.52**	-0.50**	-0.47**	-	-	-0.53**	-	-
p-value	0.01	0.02	0.01	-	-	0.01	-	-
Urban population (% of total)	-	-	-	0.91***	0.83***	-	0.85***	**0.58**
p-value	-	-	-	0.00	0.00	-	0.00	
Total natural resources rents (% of GDP)	0.00	0.08	0.14	-0.27	-0.38	0.15	-0.39	-0.11
p-value	1.00	0.83	0.68	0.49	0.25	0.64	0.23	-
Electricity produced from fossil fuels (% of total elecetricity production)	-0.93**	-	-	-	-	-	-	-
p-value	0.01	-	-	-	-	-	-	-
Electricity production from hydroelectric sources (% of total)	-1.14***	-	-	-	-	-	-	-
p-value	0.00	-	-	-	-	-	-	-
Electricity production from renewable sources, excluding hydroelectric sources (% of total)	-	1.07***	0.83**	0.92**	0.73**	0.74**	0.72***	**0.23**
p-value	-	0.00	0.02	0.01	0.04	0.03	0.04	
GINI index	-	-	-1.08**	-0.96**	-0.75**	-	-0.76***	**-0.18**
p-value	-	-	0.04	0.01	0.01	-	0.01	
GDP per head in 2008 (current US$)	-	-	-	0.00	0.00	-	0.00	0.03
p-value	-	-	-	0.59	0.83	-	0.90	
Asia dummy	-	-	-4.39	-	-	-	-	-
p-value	-	-	0.61	-	-	-	-	-
Latin America dummy	-	-	15.17	-	-	-	-	-
p-value	-	-	0.12	-	-	-	-	-
constant	163.33***	52.85**	100.56***	29.93*	16.67	47.42**	17.34	-
p-value	0.00	0.01	0.00	0.05	0.18	0.02	0.16	-

Notes: Model 4 excludes Israel. Models 5 and 7 exclude Israel, Namibia, Botswana, Egypt and Panama due to the leverage plot in Figure B1. In model 7, the renewable energy generation variable is interacted with a dummy for countries with a negative energy balance.

Table B3 - Countries considered in the various models of the study

Country	Models where the country was included	Countries with a negative energy balance in 2009	Year of Gini coefficient
Algeria	(1,2,3,4,5,6,7)		1995
Argentina	(1,2,3,4)		2009
Bolivia	(1,2,3,4,5,6,7)		2004
Botswana	(1,2,3,4,6)		1994
Brunei Darussalam	(1,2,6)		2009
Cambodia	(1,2,3,4,5,6,7)	X	2009
Cameroon	(1,2,3,4,5,6,7)		2001
Colombia	(1,2,3,4,5,6,7)		2009
Congo, Dem. Rep.	(1,2,6)		2009
Congo, Rep.	(1,2,6)		2009
Costa Rica	(1,2,3,4,5,6,7)	X	2009
Cote d'Ivoire	(1,2,3,4,5,6,7)		2002
Dominican Republic	(1,2,3,4,5,6,7)	X	2009
Egypt, Arab Rep.	(1,2,3,4,6)		2004
El Salvador	(1,2,3,4,5,6,7)	X	2009
Ghana	(1,2,3,4,5,6,7)		1999
Guatemala	(1,2,3,4,5,6,7)	X	2004
Honduras	(1,2,3,4,5,6,7)	X	2009
Indonesia	(1,2,3,4,5,6,7)		2009
Iran, Islamic Rep.	(1,2,3,4,5,6,7)		2005
Israel	(1,2,3,4,6)	X	2001
Jamaica	(1,2,3,4,6)	X	2004

(continues)

Table B3 - Countries considered in the various models of the study

(continued)

Country	Models where the country was included	Countries with a negative energy balance in 2009	Year of Gini coefficient
Morocco	(1,2,3,4,5,6,7)	X	1999
Mozambique	(1,2,3,4,5,6,7)		2002
Namibia	(1,2,3,4,6)		1993
Pakistan	(1,2,3,4,5,6,7)		2005
Panama	(1,2,3,4,6)	X	2009
Paraguay	(1,2,3,4,5,6,7)		2009
Peru	(1,2,3,4,5,6,7)	X	2009
Philippines	(1,2,3,4,5,6,7)		2009
Qatar	(1,2,6)		2009
Syrian Arab Republic	(1,2,6)		2009
Trinidad and Tobago	(1,2,6)		2009
Senegal	(1,2,3,4,5,6,7)	X	2001
Sri Lanka	(1,2,3,4,5,6,7)	X	2009
Sudan	(1,2,3,4,5,6,7)		2009
Togo	(1,2,6)	X	2009
Tunisia	(1,2,3,4,5,6,7)	X	2000
Uruguay	(1,2,3,4,5,6,7)	X	2009
Venezuela, RB	(1,2,3,4,5,6,7)		2005
Zambia	(1,2,3,4,5,6,7)		2009

Note: 2009 Gini coefficients were taken from the 2013 WDI database, those referring to previous years from the UNU-Wider database.

Table B4 - Correlation matrix

		a.	b.	c.	d.	e.	f.	g.	h.	i.	l.	m.	n.
a.	Domestic credit to private sector (% of GDP)	1											
b.	Rural population (% of total population)	-0.37	1										
c.	Urban population (% of total)	0.37	-1	1									
d.	Total natural resources rents (% of GDP)	-0.35	-0.12	0.12	1								
e.	Electricity production from renewable sources, excluding hydroelectric (%)	0.01	-0.06	0.06	-0.31	1							
f.	Electricity production from hydroelectric sources (% of total)	-0.18	0.03	-0.03	0.00	-0.08	1						
g.	GINI index	0.18	-0.16	0.16	-0.27	0.10	0.52	1					
h.	Years of Schooling	0.38	-0.44	0.44	-0.08	-0.03	-0.18	0.11	1				
i.	Years of Secondary Schooling	0.36	-0.40	0.40	0.05	-0.24	-0.22	-0.10	0.87	1			
l.	GDP per head in 2008 (current US$)	0.61	-0.64	0.64	-0.21	0.00	-0.16	0.03	0.52	0.43	1		
m.	Electricity produced from fossil fuels (% of total electricity production)	0.18	-0.02	0.02	0.08	-0.16	-0.97	-0.54	0.18	0.28	0.16	1	
n.	Access to electricity (% of population)	0.42	-0.69	0.69	-0.01	0.22	-0.27	-0.12	0.53	0.61	0.41	0.21	1

Figure B1 - Leverage - squared residuals plot of Model 4 in Table B2