What happened to efficiency in electricity industries after reforms?

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Abstract

The last two decades have witnessed widespread power market reforms in both developed and developing countries that have cost billions of dollars. Among the key aims (and assumptions) of these reforms, there has always been realization of improvements in power sector efficiency. This paper questions the validity of this hypothesis. Using panel data from 92 countries covering the period 1982–2008, empirical models are developed and analyzed. The research findings suggest that the impact of the reforms on electricity industry performance is statistically significant but also limited. The results imply that, after controlling for country-specific variables, application of liberal market models in electricity industries slightly

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increases efficiency in power sector. Besides, we detect a positive relationship between reform process and the percentage share of network (transmission and distribution) losses in total electricity supplied; meaning that as countries take more reform steps the network losses as a fraction of power generated tend to increase. Moreover, the study puts forward that income level and other country specific features are more important determinants of industry efficiency than the reform process. Overall, contrary to expectations of substantial increases in sector efficiency, the paper concludes that introducing a decentralized market model with competition in the electricity sector has a limited increasing effect on power industry performance.

Keywords: *Models with panel data (C33); model construction and estimation (C51); electric utilities (L94); power market reform; electricity industry efficiency*

1. Introduction

Improvement in efficiency constitutes one of the two principal aims in any power sector reform program[1]. It is typically argued that, even in the short run, the reform process introduces competition, which in turn encourages economic units with the lowest costs to operate in the market. Besides, over the longer term, markets present better incentives for new entrants; and new entrants with more efficient technologies place additional upward pressure on efficiency levels. Overall, it is expected that the introduction of reforms in the electricity markets leads to higher efficiency levels. The main aim of this paper is to discover whether

[1] The other principal aim of the power sector reforms has been reductions in electricity price cost-margins. We analyzed the impact of the reforms on price-cost margins elsewhere. For details, please see Erdogdu, E., 2011. The impact of power market reforms on electricity price-cost margins and cross-subsidy levels: A cross country panel data analysis. Energy Policy 39, 1080-1092.

the power market reforms realize these expectations. The paper also aims at clarifying whether the impact of power sector reform on efficiency differs among countries according to their development level and regional characteristics. Empirical econometric models are estimated and then analyzed to observe the effect of electricity market reform process on power industry efficiency. The econometric models are designed using panel data from 92 countries where a reform process in the electricity industry has been initiated. The dataset covers the period from 1982 to 2008.

We try to answer the following research questions: (i) what is the impact of power market reforms on electricity industry performance? (ii) are there systematic differences among various country groups, in relation to development level and region, concerning the influence of reforms on electricity sector efficiency? (iv) what are the other factors that influence efficiency levels in power industry and how much are they influential relative to reform process?

In line with our research questions, the main hypothesis we test in this study (Hypothesis 1) is given below. Besides the main hypothesis, we also check for the following assumption (Hypothesis 2).

Hypothesis 1. As countries introduce more and more reform steps, efficiency levels in the power industries increase.

Hypothesis 2. There is a positive relationship between income level and efficiency in the power industry.

Based on our hypotheses above, we expect a positive relationship between reform process and income level on the one hand **and** on the other hand plant load factor, net generation per employee in electricity industry, and net generation per employee in utility industries. We also expect a negative relationship between reform score and income level variables **and** distance from optimal reserve margin and fraction of electricity losses in total electricity supplied variables.

The paper proceeds as follows. Next section provides a literature review on the impact of the electricity market reforms on efficiency levels. Section 3 describes data. Section 4 summarizes the methodological framework. Following section presents empirical analysis and discusses the results, followed by a section on limitations of the study. The last section concludes.

2. Literature review

In this section, we review empirical literature on the impact of electricity sector reform process on the efficiency levels in electricity industries. There is an extensive body of literature on electricity market reforms but most of it is in the form of opinion and discussion without any empirical analysis. Jamasb et al. (2004) classify approaches to analyzing electricity reforms into three broad categories: (i) econometric methods, (ii) efficiency and productivity analysis methods, and (iii) individual or comparative case studies. They argue that econometric studies are best suited to the analysis of well-defined issues and the testing of hypotheses through statistical analysis of reform determinants and performance. According to them, efficiency and productivity analyses are suitable for measuring the effectiveness with which inputs are transformed into outputs, relative to best practice. Jamasb et al. (2004) also maintain that single or multi-country case studies are suitable when in-depth investigation or qualitative analysis is needed. Within this classification, our study falls into the first category. Therefore, in this section we summarize econometric studies that focus on cross-country evidence on the impact of electricity market reforms on efficiency. Non-econometric studies, econometric studies looking at just one or a few countries and studies that are not directly related to electricity markets fall outside the scope of this section.

The empirical analysis by Steiner (2001) constitutes one of the earliest analysis of the reform process. In her study, Steiner (2001) conducted a panel data analysis including electricity price, ratio of industrial to residential electricity price, capacity utilization rate and reserve margin. Using these variables, she tried to measure the competitive aspects and the cost efficiency of reform. She also looked at some reform elements separately, including unbundling, wholesale power pool, third party access to transmission and privatization. The study found that electricity market reforms generally induced a decline in the industrial price and an increase in the price differential between industrial customers and residential customers, indicating that industrial customers benefit more from the reform. She also found that unbundling is not associated with lower prices but is associated with a lower industrial to residential price ratio and higher capacity utilization rates and lower reserve margins.

Bacon and Besant-Jones (2001) tested two hypotheses in their study. The first one stated that country policy and institutions are positively correlated with reform, and second was that country risk is negatively correlated with reform. Their results supported both hypotheses. The coefficient on the policy indicator and the coefficient on the risk indicator were significant and had the expected signs. In addition, they detected some regional effects. For instance, they found that Latin American and Caribbean countries are more likely to reform while countries in the Middle East and Africa are more likely to take fewer reform steps.

The study by Ruffin (2003) dealt with the institutional determinants of competition, ownership and extent of reform in electricity reform process. The institutional determinants employed are different measures of judicial independence, distributional conflict and economic ideology. The study used a cross-section OLS regression analysis of a set of models with observations of up to 75 developed and developing countries that reformed their electricity industries during the 1990s. Ruffin (2003) also used institutional explanatory variables with the electricity reform scores that reflect the extent of reform. The study found that the relation between judicial independence on the one hand, and competition and ownership on the other, is ambiguous; i.e. the coefficients are often insignificant or, when significant, their sign shifts across models. Besides, greater distributional conflict was found to be significantly correlated with a higher degree of monopoly. Moreover, the results showed that the relation between economic ideology favoring competition and private ownership was generally positive and significant. The results also pointed out that there is a positive relationship between judicial independence and reform scores. Furthermore, economic ideology showed a positive and significant relation with the reform score in this study.

Fiorio et al. (2007) questioned the widespread beliefs that public ownership can be an impediment to other reforms and that it leads to production inefficiency. To test this and examine the reform paradigm in general, they considered electricity prices and survey data on consumer satisfaction in the EU-15. Their empirical findings rejected the prediction that privatization leads to the lower prices or to increased consumer satisfaction. They also found that country specific features tend to have a high explanatory power, and the progress toward the reform paradigm is not systematically associated with lower prices and higher consumer satisfaction.

Zhang et al. (2008) provided an econometric assessment of the effects of privatization, competition and regulation on the performance of the electricity generation industry using panel data for 36 developing and transitional countries over the period 1985-2003. The study identified the impact of these reforms on generating capacity, electricity generated, labor productivity in the generating sector and capacity utilization. The main conclusions were that on their own privatization and regulation (PR) do not lead to obvious gains in economic performance, though there are some positive interaction effects. By contrast, they concluded, introducing competition seemed to be effective in stimulating performance improvements.

Based on this literature review on cross-country econometric studies related to electricity market reforms, we may argue that present econometric evidence on the impact of the reform process on efficiency is quite limited and will take more time to emerge. Therefore there exists a huge research gap here. To best of our knowledge, the present paper constitutes the most extensive study in this area in terms of both scale and scope.

3. Overview of data

Our data set is based on a panel of 92 countries for a period from 1982 to 2008. Year 1982 is selected as the starting date for the study because at that time electricity market reform was initiated for the first time in Chile. The final date, 2008, represents the last year for which data are available at the time the research is conducted. The sample countries in our analysis cover all countries where an electricity market reform process has initiated so far; that is, those countries having a reform score of at least 1 or above as of 2008. Because of the missing observations, our panel is unbalanced.

The variables used in the study are: electricity market reform score; plant load factor; distance between actual and optimal reserve margin; transmission and distribution losses as a fraction of power generated; net generation per employee in electricity industry; net generation per employee in utility (electricity, gas and water) industries; and income level (GDP per capita). We also divided all countries in our dataset into five groups, namely (1) developed countries and (2) developing countries in Africa, (3) in America, (4) in Asia and Oceania and (5) in Euro-Asia. This classification is based on World Bank (2010a). We included a dummy variable for each group of country into our dataset. Countries in our analysis and the groups they belong to are seen in Figure 1.

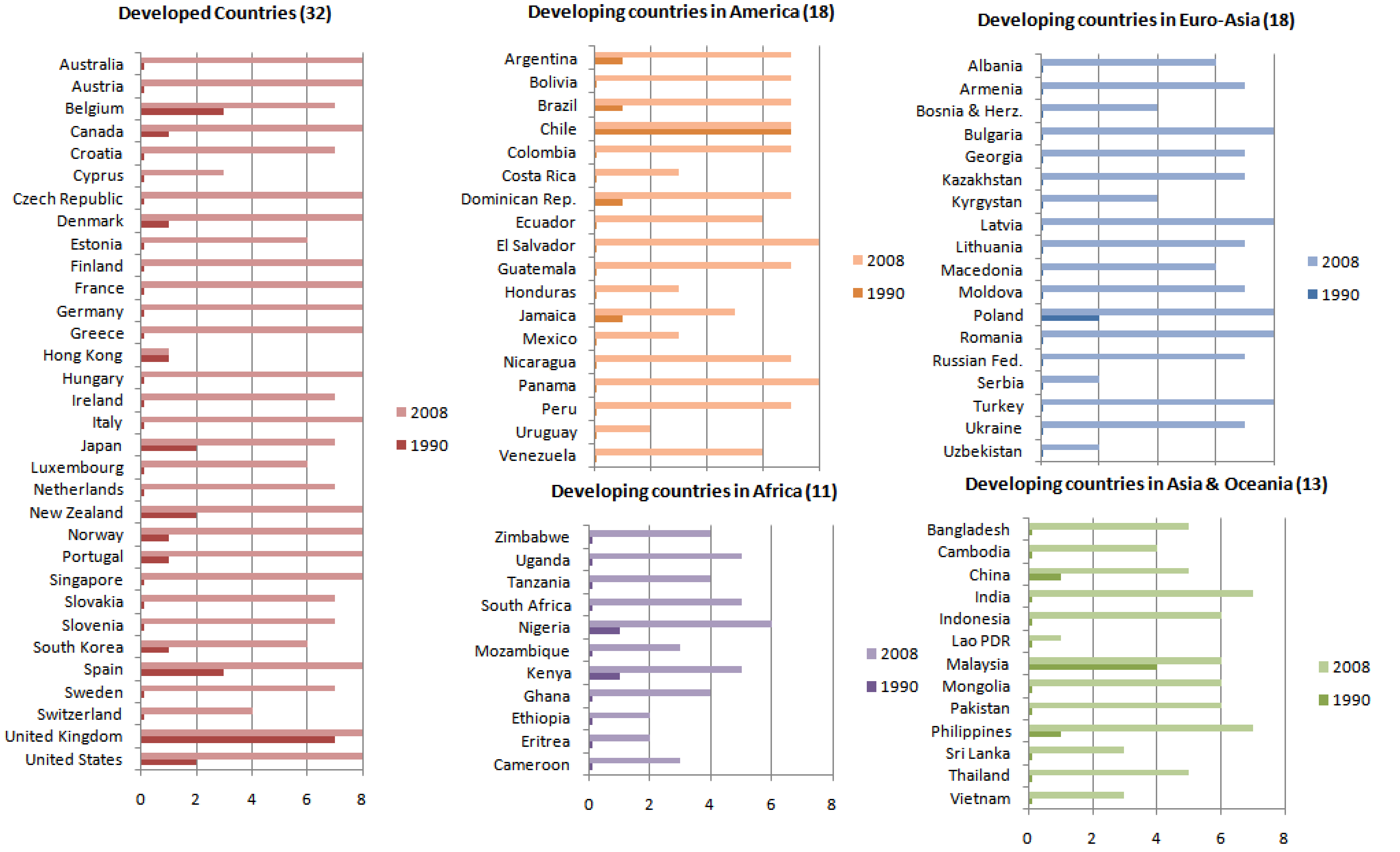
Electricity market reform score variable takes the values from 0 to 8; depending on how many of the reform steps below have been taken in each country and each year. To build this variable, we created 8 dummy variables for each of the reform steps. These are: (1) introduction of independent power producers, (2) corporatization of state-owned enterprises, (3) law for electricity sector liberalization, (4) introduction of unbundling, (5) establishment of electricity market regulator, (6) introduction of privatization, (7) establishment of wholesale electricity market, (8) choice of supplier. Then, we calculated the total number of reform steps taken in each country and each year to construct our reform score variable. Dummy variables for reform steps were created by the author based on the data collected and cross-checked from various international and national web sites and a variety of papers. Figure 1 presents the change in reform score variables for the countries in our sample from 1990 to 2008.

One of the most important targets of power market reforms has been attaining a higher level of productive efficiency, also known as "technical efficiency", in the electricity sector. Productive efficiency occurs when the economy is utilizing all of its resources efficiently, producing most output from least input. Productive efficiency requires that all firms operate using best-practice technological and managerial processes. By improving these processes, an economy or business can increase its efficiency further. The concept, at its optimum, represents a situation where no more output can be achieved from the given inputs. In our analysis, we used four indicators representing the efficiency in the power industry, namely (i) plant load factor; (ii) distance between actual and optimal reserve margin; (iii) transmission and distribution losses as a fraction of power generated; and (iv) net generation per employee.

Plant load factor (PLF) is a measure of average capacity utilization. It is a measure of the output of a power plant compared to the maximum output it could produce. Therefore a higher load factor usually indicates more output and a lower cost per unit. PLF is affected by non-availability of fuel, maintenance shut-down, unplanned break down and non-generation. For example, consumption pattern may fluctuate lower in nights and some plants stop generating electricity. PLF equals to gross electricity generation divided by installed capacity multiplied by number of hours in a year[2]. Data on gross electricity generation and installed capacity for each country and for each year are obtained from International Energy Agency (IEA) and US Energy Information Administration (IEA, 2010a; US EIA, 2010).

[2] PLF = Gross electricity generation / (Installed capacity x Number of hours in a year)

Figure 1. Electricity market reform scores of countries in the sample in 1990 and 2008



Another indicator of efficiency employed here is the distance between actual and optimal reserve margin[3]. The reserve margin is calculated as the difference between capacity and peak demand, divided by peak demand. When introducing electricity sector reform, countries attempt to plan for their energy consumption needs to satisfy demand with a sufficient, though not excessive, buffer. As a result, utilization of the reserve margin as a dependent variable would be inappropriate because too much reserve margin means inefficient allocation of resources. Therefore, the distance of the reserve margin from a benchmark is employed in this study. In her paper, Steiner (2001) suggests that 15% may be taken as the optimal reserve margin. The indicator in this paper also uses 15% cent as the optimal reserve margin benchmark. We do not attempt to distinguish between over and under capacity and assume that any deviation from 15% reserve margin level results in inefficiency in the industry. Peak load data are taken from IEA (2010b).

Data on transmission and distribution losses as a fraction of power generated are created by using data from IEA and US Energy Information Administration (IEA, 2010a; US EIA, 2010). Any decrease in the share of network losses means an increase in sector efficiency. Therefore, the share of network losses constitutes the third measure of efficiency in our analysis.

Net generation per employee is the last efficiency indicator in our study. It represents the labor productivity in the sector. A higher net generation per employee figure represents a relatively more efficient industry. This variable is calculated by dividing the net electricity generation by the number of people employed in the industry. The data on net electricity generation come from IEA and US Energy Information Administration (IEA, 2010a; US EIA,

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[3] The distance between actual and optimal reserve margin = $|0.15 - [(\text{Installed capacity} - \text{Peak load})/\text{Peak load}]|$

2010). Employment in electricity industry data are extracted from EU KLEMS database (EU, 2010). This dataset covers 17 countries. Besides, aggregate data on total employment in utility (electricity, gas and water) industries are collected for 60 countries from European Union, Eurostat and United Nations (EU, 2010; Eurostat, 2010; UN, 2010). As this variable significantly increases the extent of our analysis, we used it as a proxy for the changes in employment in power industries.

GDP per capita variable is used as a control variable in our study and it represents a part of the country specific features that may have an influence on efficiency level in the power industry. Data on GDP per capita are obtained from World Bank (2010b). Table 1 shows descriptive statistics for the variables in our analysis.

Table 1. Descriptive statistics of the variables in the model

Variables (Units)	**Type of variable in the analysis**	**# of obs.**	**# of countries**	**Mean**	**St. dev.**	**Min.**	**Max.**
Plant load factor	-	2096	88	0.434	0.108	0.016	0.770
Log of plant load factor	Dependent	2096	88	-0.884	0.375	-4.116	-0.261
Distance between actual and optimal reserve margin	Dependent	593	28	0.361	0.263	0.000	1.395
Electricity losses as a fraction of power generated	Dependent	2186	90	0.132	0.081	0.000	0.588
Net generation per employee in electricity industry(GWh/million people)	-	322	17	3.382	1.842	0.558	9.788
Log of net generation per employee in electricity industry	Dependent	322	17	1.055	0.606	-0.584	2.281
Net generation per employee in utility industries (GWh/million people)	-	1011	60	1.623	1.425	0.031	8.973
Log of net generation per employee in utility industries	Dependent	1011	60	0.093	0.946	-3.462	2.194
Electricity market reform score	Independent	2484	92	2.569	2.935	0	8
Square of electricity market reform score	Independent	2484	92	15.209	21.816	0	64
GDP per capita, PPP (current international thousand US$)	-	2289	91	10.106	10.613	0.187	79.485
Log of GDP per capita	Independent	2289	91	1.695	1.230	-1.679	4.376

4. Methodological framework

It is almost impossible to observe the real impact of power market reforms on efficiency without separating the effects of market reform from country specific features. Therefore, in our study, we make this distinction by describing efficiency in electricity industry as a function of

(a) electricity market reform score (a comparable cross-country reform indicator),

(b) a control variable (income level)

(c) country-specific effects[4],

(d) other unobserved variables that influence efficiency in the industry.

These variables are then used in panel regressions to assess their impact on power industry efficiency. In panel regressions, the exploitation of both cross-country and time-series dimensions of the data allows for control of country-specific effects. Apart from reform process, efficiency in the power industry of a specific country is expected to be influenced mainly by income level of that particular country. Countries with higher GDP per capita figures tend to use more efficient (and expensive) technologies in generation, transmission and distribution of electricity, which results in a more efficient sector. In our model, we include income level variable in order to isolate the effect of reform process on efficiency.

We formulate regression equations as below to analyze the impact of electricity industry reform on power sector efficiency.

$$Y_{it} = \beta_1 + \sum_{j=2}^{k} \beta_j X_{jit} + \sum_{p=1}^{s} \gamma_p Z_{pi} + \delta t + \varepsilon_{it} \quad (1)$$

[4] These are assumed to be exogenous and to exist independently of reform process, but may explain a portion of the variation in efficiency levels.

In the model, i and t represent unit of observation and time period, respectively. j and p are indices used to differentiate between observed and unobserved variables. X_{ji} and Z_{pi} represent observed and unobserved variables, respectively. X_{ji} includes both reform variable and control variable. Y_{it} is dependent variable. ε_{it} is the disturbance term and t is time trend term. Because the Z_{pi} variables are unobserved, there is no means of obtaining information about the $\sum \gamma_p Z_{pi}$ component of the model. For convenience, we define a term α_i, known as the unobserved effect, representing the joint impact of the Z_{pi} variables on Y_{it}. So, our model may be rewritten as follows:

$$Y_{it} = \beta_1 + \sum_{j=2}^{k} \beta_j X_{jit} + \alpha_i + \delta t + \varepsilon_{it} \tag{2}$$

Now, the characterization of the α_i component is crucially important in the analysis. If control variables are so comprehensive that they capture all relevant characteristics of the individual, there will be no relevant unobserved characteristics. In that case, the α_i term may be dropped and pooled data regression (OLS) may be used to fit the model, treating all the observations for all time periods as a single sample. However, since we are not sure whether control variables in our models capture all relevant characteristics of the countries, we cannot directly carry out a pooled data regression of Y on X. If we were to do so, it would generate an omitted variable bias. Therefore we prefer to use either a Fixed Effects (FE) or Random Effects (RE) regression. In FE model, the country-specific effects (α_i) are assumed to be the fixed parameters to be estimated. In RE model, the country-specific effects (α_i) are treated as stochastic. The fixed effect model produces consistent estimates, while the estimates obtained from the random effect model will be more efficient. Efficiency levels in the power industries may or may not be country specific as, in some cases, international or regional organizations (e.g. EU) impose rules on electricity industries that guarantee a minimum level of efficiency throughout a specific region. Therefore, we cannot be sure whether the observations in our model may be described as being a random sample from a given population; and cannot directly decide which regression specification (FE or RE) to use. This will be decided in the course of the analysis based on relevant econometric tests, namely Hausman test and Breusch and Pagan Lagrangian Multiplier (BPLM) test.

5. Empirical analysis and discussion of the results

Throughout our analysis, we estimate five groups of models to explain the impact of the reform process on the efficiency in electricity industry. A group of models is estimated for each efficiency indicator and each group includes an overall model including all countries and some other sub-models for specific country groups[5]. In total, 21 models are estimated. Using logarithms of variables enables us to interpret coefficients easily and is an effective way of shrinking the distance between values. Therefore, we transform GDP per capita, plant load factor, net generation per employee in electricity industry, and net generation per employee in utility industries variables into logarithmic form. We then use these new transformed variables in our models. We also admit that the relationship between reform score variable and any efficiency indicator may be quadratic rather than linear. Therefore we also include square of reform score variable into our regressions as a separate variable. However, we observe that, in some cases, inclusion of this new variable makes previously significant reform score variable insignificant. In such cases, we avoid including square of reform score variable into the model.

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[5] FE estimation results do not let us detect the differences between country groups as variables that do not vary over time (like dummies for separating country groups) are dropped in FE estimation. In order to observe possible differences between country groups, we estimate separate models for each country group.

We perform the empirical analysis by estimating the specification given in Equation (2) for each model[6]. However, as mentioned before, we cannot directly decide which regression specification (FE or RE) to use. Therefore, we apply the Hausman test for fixed versus random effects in each model. To perform this test, we first estimate the fixed effects model (which is consistent) and store the estimates, then estimate the random-effects model (which is efficient) and run the test. Since we prefer a significance level of 5%, any p-value less than 0.05 implies that we should reject the null hypothesis of there being no systematic difference in the coefficients. In short, Hausman test with a p-value up to 0.05 indicates significant differences in the coefficients. Therefore, in such a case, we choose fixed effects model. However, if the p-value from Hausman test is above 0.05, we cannot reject the null hypothesis of there being no systematic difference in the coefficients at 5% level. In short, in these cases, the Hausman test does not indicate significant differences in the coefficients. Therefore, we provisionally choose random effects. After that, we apply Breusch and Pagan Lagrangian Multiplier (BPLM) test for random effects in order to decide on using either pooled OLS or random effects in our analysis. This test is developed to detect the presence of random effects. In this test, the null hypothesis is that variances of groups are zero; that is, there is no unobserved heterogeneity, meaning that all groups are similar. If the null is not rejected, the pooled regression model is appropriate. That is, if the p-value of BPLM test is below 0.05, we reject the null, meaning that the random effects specification is the preferred one. If it is above 0.05, we prefer pooled OLS specification to carry out our regression. Table 2 shows a summary of estimation results that presents statistically significant coefficients and their standard errors. Full details of estimation results are provided in Appendix 1; including full estimation output, number of observations and countries included in each model, results of Hausman and BPLM tests and preferred specifications based on these tests. Appendix 1 also

[6] Throughout the paper, model estimations are carried out by Stata 11 and Eviews 7.

shows the optimal number reform steps for each country group and efficiency indicator depending on the coefficient estimates for reform score variable(s).

It is not easy to draw conclusions about the impact of extensive electricity market reforms in various countries from empirical work that focuses on a single market or from other country-specific anecdotal discussion of reform processes because neither type of study distinguishes the effects of reform from country-specific features. Therefore, our empirical approach was to take advantage of the diversity in electricity reform patterns in various countries and to control for income level variable to predict five efficiency indicators: (i) plant load factor, (ii) distance from optimal reserve margin, (iii) transmission and distribution losses as a fraction of power generated, (iv) net generation per employee in electricity industry, and (v) net generation per employee in utility industries. Panel analysis of efficiency trends (using reform variable and country income level) offers objective evidence on the observed impact of reforms at a macro level. Based on the empirical results presented in Table 2, it is helpful to discuss the impact of reform score variable on each efficiency indicator one by one.

Table 2. Summary of estimation results

Dependent Variables → **Explanatory Variables ↓**		**Log of plant load factor**	**Distance from optimal reserve margin**	**Electricity losses as a fraction of power generated**	**Log of net generation per employee in electricity industry**	**Log of net generation per employee in utility industries**
Reform score	*All countries*	0.034*** *(4.1)*	-0.038*** *(-4.4)*	0.02*** *(13.59)*	0.022*** *(5.37)*	0.019*** *(4.41)*
	Developed countries	0.043*** *(6.69)*	-0.032*** *(-3.48)*	0.001** *(2.14)*	-	0.024*** *(6.89)*
	Developing countries in Africa	*NS*	-0.119*** *(-3.79)*	0.049*** *(6.02)*		-
	Developing countries in America	0.026* *(1.76)*		0.036*** *(9.47)*		0.116*** *(3.12)*
	Developing countries in Asia and Oceania	0.082*** *(5.29)*		-0.009* *(-1.76)*		*NS*
	Developing countries in Euro-Asia	-0.066*** *(-4.81)*		0.043*** *(8.83)*		-0.228*** *(-5.07)*
Square of reform score	*All countries*	-0.006*** *(-5.77)*	0.005*** *(5.37)*	-0.002*** *(-11.29)*	-	-
	Developed countries	-0.006*** *(-7.34)*	0.005*** *(4.63)*	0.000*** *(-2.62)*		-
	Developing countries in Africa	*NS*	0.012*** *(3.89)*	-0.008*** *(-5.45)*		-
	Developing countries in America	*NS*		-0.004*** *(-8.74)*		-0.018*** *(-3.31)*
	Developing countries in Asia and Oceania	-0.009*** *(-3.98)*		0.002** *(2.46)*		0.023* *(1.91)*
	Developing countries in Euro-Asia	0.004** *(2.38)*		-0.005*** *(-6.94)*		0.031*** *(6.89)*
Log of GDP per capita	*All countries*	0.265*** *(12.48)*	-0.141*** *(-5.07)*	-0.041*** *(-13.06)*	0.785*** *(22.36)*	0.581*** *(17.8)*
	Developed countries	0.157*** *(9.44)*	-0.176*** *(-5.74)*	-0.011*** *(-6.21)*	-	0.642*** *(22.92)*
	Developing countries in Africa	2.124*** *(9.72)*	*NS*	*NS*		-
	Developing countries in America	0.12*** *(3.22)*		-0.044*** *(-4.71)*		0.545*** *(6.16)*
	Developing countries in Asia and Oceania	0.098*** *(3.47)*		-0.036*** *(-3.93)*		0.708*** *(5.15)*
	Developing countries in Euro-Asia	0.224*** *(6.01)*		-0.06*** *(-5.4)*		*NS*
Constant	*All countries*	-1.344*** *(-43.18)*	0.785*** *(11.07)*	0.185*** *(25.46)*	-1.392*** *(-8.91)*	-1.296*** *(-19.32)*
	Developed countries	-1.292*** *(-29.91)*	0.896*** *(10.97)*	0.106*** *(23)*	-	-1.441*** *(-11.13)*
	Developing countries in Africa	-0.968*** *(-15.38)*	0.309*** *(2.89)*	0.134*** *(4.16)*		-
	Developing countries in America	-1.099*** *(-23.71)*		0.205*** *(12.05)*		-1.442*** *(-9.7)*
	Developing countries in Asia and Oceania	-0.989*** *(-20.64)*		0.183*** *(13.97)*		-1.717*** *(-29.36)*
	Developing countries in Euro-Asia	-1.177*** *(-13.93)*		0.217*** *(11.45)*		*NS*

Standard errors are shown in parentheses () after coefficients.
"-": Not a variable in the model.
"NS": The coefficient is not significant even at 10% level.
**** Coefficient that is significant at 1% level.*
*** Coefficient that is significant at 5% level.*
** Coefficient that is significant at 10% level.*

First of all, overall model estimation results for plant load factor indicator are in line with our expectations. The results suggest that on average any additional reform step or a rise in income increases plant load factor (and thereby efficiency). However, the positive impact of reform steps is limited up to 5 reform components. Any additional reform step after fifth one results in a decline in plant load factor (and therefore in efficiency). However, when we examine sub models in this category, we notice important differences among country groups. For instance, in developing countries in Asia and Oceania and developed countries, the optimal number of reform steps is quite high (7 and 8 respectively), meaning that almost any additional reform step in these countries increases efficiency in the power industry. On the other hand, optimal number for reform elements in developing countries in Euro-Asia region is 0, implying that any reform step in this area decreases efficiency in the sector. The impact of reform score variable in this first group of models is quite limited. Even at its optimum, its impact of reform score on efficiency is less than 0.1% in any model. In contrast, income level is an important determinant of efficiency level. For instance, overall model results imply that a 10% increase in GDP per capita results in 2.7% rise in plant load factor.

As for distance from optimal reserve margin variable, again results are more or less in conformity with our expectations, that is both reform score and income level variables seem to be negatively correlated with distance from optimal reserve margin variable. Due to limited data, we could use observations on 25 developed and 3 developing countries for the models in this group. Our results suggest that reform steps have definitely contributed to efficiency but again this impact is rather limited. For developed countries, optimum number of reform steps is 6 while this figure for developing countries is 8, suggesting that according to this criterion all reform steps are beneficial to electricity market efficiency in developing countries.

The results for the third indicator, transmission and distribution losses as a fraction of power generated, are completely in conflict with the assumptions towards increased efficiency in the sector to be realized as a result of reforms. There seems to be a positive relationship between reform score and share of network losses, suggesting that any reform step increases the fraction of losses in total electricity supply and, therefore, reduces efficiency. For that reason, obviously, the optimal number of reform steps in terms of losses is zero for almost all countries. The only exception to this trend is seen in countries in Asia and Oceania where the optimal number of reform steps is 4. Actually, the negative effect of market liberalization on the network losses may be regarded as similar to the positive effect of market liberalization on the plant load factor and other efficiency indicators. Indeed, this result may conform to the economic theory that with the introduction of independent power producers (IPPs) network losses exceed the network losses of a regulated vertically integrated monopoly (which was usually the market structure prior to liberalization) because as a result of unbundling (and assuming that the grid access is distance independent) not only IPPs but also incumbents locate new power plants at locations which are optimized for other aspects than transmission losses[7]. In addition, in the overall model and all sub models, GDP per capita seems to be negatively correlated to fraction of electricity losses, meaning that any increase in income level results in a decline in network losses, which confirms the idea that wealthier countries use more advanced transmission and distribution technologies that minimize the network losses.

We could obtain net generation per employee variable using employment in electricity industry data for 17 countries. This figure rises to 60 if we use aggregate data on employment in utility (electricity, gas and water) industries to construct this variable. To exploit both data,

[7] I thank anonymous Reviewer #1 for suggesting this comment.

we estimated models using variables created from both sources of data. To begin with, we estimated models to explain the impact of reform process on net generation per employee in electricity industry using data from 17 countries. Our results show that all reform steps contribute to sector efficiency by increasing the net generation per employee in the electricity sector. The income level variable is also positively correlated with this indicator and its impact is much stronger compared to reform score variable. For instance, net generation per employee in the electricity sector increases about 0.2% when a developed country takes all 8 reform steps, while this indicator rises by 7.9% as a result of just a 10% increase in GDP per capita. While evaluating these results it is better to keep in mind that estimation procedure for this model includes data on developed countries only.

To improve the extent of our analysis, we also use employment in utility (electricity, gas and water) industries variable as a proxy for efficiency in power industry. Our results for this group of models are quite similar to those from previous group with the exception that reform steps seem to cause efficiency to decline in Euro-Asian developing countries. For developed countries and developing countries in America, reforms seem clearly to contribute to efficiency. Similar to all previous models, the impact of reform score variable on employment level is again rather limited, while income variable is responsible for most of the variation in efficiency levels.

Finally, in our empirical analysis, we witnessed that country specific features tend to have the highest explanatory power. For instance, in Model 4[8], compared to Hungary, net generation

[8] Cross-section fixed effects in Model 4 are as follows: Australia: 0.06, Austria: -0.43, Belgium: 0.16, Czech Rep.: -0.46, Denmark: -0.05, Estonia: -0.75, Finland: 0.23, France: 0.34, Germany: -0.49, Hungary: -0.90, Japan: 0.64, Portugal: 0.08, Slovenia: -0.43, S. Korea: 0.82, Spain: 0.67, UK: 0.25, US: 0.27.

per employee in electricity industry is 1.7% higher in South Korea due to country-specific unobserved factors.

In a nutshell, the research results suggest that, after controlling for country-specific variables, panel estimation of various efficiency indicators as dependent variables confirms the expectation that power market reforms lead to higher efficiency levels. However, reforms tend to have a very limited impact on efficiency levels. Our findings also imply that the reforms fail to decrease network losses. So, we found practical evidence implying that introduction of a competitive model in electricity markets has an increasing effect on sector performance but this effect is rather small. Besides, in most cases, we see that country specific effects and income level tend to be important factors explaining variations in efficiency levels. Overall, derived from empirical analysis, the paper concludes that the evidence, at least at this stage of reforms, neither verifies nor falsifies the argument that a liberal market model based on competition is beneficial in terms of power market efficiency. We detected a very limited increase in performance as a result of reforms but this benefit may well disappear when we take into account the huge cost of the reform.

To sum up, based on our results, for the share of network losses indicator we reject Hypothesis 1, but fail to reject Hypothesis 2. For all other efficiency indicators adapted in this study, we fail to reject the hypotheses. Overall, our results reveal that the progress toward the electricity market reform is associated with higher efficiency, although this impact is limited and fluctuates a lot among country groups.

Our conclusion verifies the idea that a liberal market model (with privatization, liberalization and vertical disintegration) increases efficiency in the power industry. However, it does not necessarily follow that the reform process is an indisputable success. Our empirical findings suggest that the impact of reform process on efficiency levels is limited and that even full liberalization process increases efficiency by less than 1%. Besides, an increase in efficiency is just one of the expectations from the reform and the process should be judged based on its overall impact (not only its impact on efficiency). Furthermore, it may well be argued that the reform process has just started or is still under progress in many countries and today it is too early to measure its impact on sector performance. These and similar arguments cannot be rejected straight away. What we may argue correctly, however, is that as a result of reforms some efficiency improvements have been materialized to a limited extent.

6. Limitations of the study

The research, however, may have a number of limitations, which we acknowledge. In fact, we have no reason to believe that any of these limitations should be existent in our analysis, but cannot of course rule them out.

To begin with, like all other econometric studies on electricity reform, the issue of endogeneity can be raised in our study. In the context of efficiency in electricity industries, it is likely that just as reform process affects efficiency, efficiency level in the industry can affect reform decisions. Besides, some variables in our model may be endogenously determined. In other words, explanatory variables in our model may influence each other, as well as the pattern of efficiency levels. The analysis dealt to some extent with this potential problem by including country and year fixed effects. The country fixed effects control for country-specific propensities to reform and matters such as institutional characteristics, and year fixed effects control for any general trend in the reform of electricity sector. Endogeneity may be addressed by using instrumental and lagged variables and dynamic modeling but since these require better data we cannot employ them here. This may be, of course, an area of future research, but we have ignored these possibilities here due to lack of data.

Second shortcoming originates again from the lack of data. Due to limited nature of our data set, we could not properly account for the impact of some other variables on efficiency in power industries like institutional characteristics, technological innovations and changes to regulatory practices. For instance, a possible source of bias in our study is that the model does not control for market power or dominant generation technology in the electricity industry.

Some aspects of electricity reforms are not readily quantifiable in physical units. The main issue is that simple observation of the fact that some reform steps have been taken does not reflect their characteristics and extent (Jamasb et al., 2004). That is to say, objective comparisons across countries are inherently difficult in any study and our analysis is not an exception. The main steps of electricity reform process are usually established progressively and have a qualitative dimension. Accounting for these measures with the use of dummy variables does not reveal their true scope or intensity. To lessen the impact of this drawback, we did not use individual dummy variables for reform elements in this study. Instead, we constructed an aggregate reform score variable that reflects extent of the reform process. Although such an approach seems a practical and reasonable representation of reform dimension, we cannot argue that we reflected all characteristics of the various reform processes in our study.

Our sample includes all 92 countries where a reform process has initiated so far. However, we have some missing observations for some of the variables in our models. For instance, data on distance between actual and optimal reserve margin variable are available for 28 countries, on net generation per employee in utility industries for 60 countries and on net generation per employee in electricity industry for only 17 countries. There will be sample selection bias if the countries making this data available have differing results for the dependent variables than those which do not make data available. Moreover, different countries may have different classifications and reporting conventions, so that observations in a given data series may not have the same meaning across all countries. Taken together, any measurement error and omission of explanatory variables may bias estimates of coefficients in the models. However, in our study, omitted variables may be captured at least in part by the country-specific effects, mitigating the potential for bias.

While our analysis serves as one of the first steps in assessing the impact of reform process on efficiency levels, much work remains to be done. There is still much room for improvement within the models and data presented in this paper. A more complicated model that controls for the endogeneity might improve estimates by better controlling for factors that affect sector efficiency independent of reform process. Furthermore, as done in many other similar studies, we treated large countries like United States, Australia, Canada and India, in which the development of liberalization varies from state to state, in the same way as developing countries that came late to liberalization. Thus, in the future, we need to develop new methods to reflect the impact of the size and scale of the countries in our sample.

7. Conclusion

The true value of electricity reform is a matter of empirical testing rather than theoretical debate. Opponents of the reform may point to spectacular reform failures (e.g. California disaster), or its advocates may try to get general conclusions from some success stories of a few reforming countries (e.g. NordPool). However, what is really needed is a complete study of the impact of reforms within the context of a well-defined model construction. Besides, today, there are data on electricity market reforms going back about two decades and available data start to let us meaningfully establish which market model and industry structure optimize social welfare. This study tried to fill the gap by offering a macro level econometric analysis on the possible effects of reform process.

One of the main *expectations* from power market reform has been the realization of vast efficiency improvements in the sector, while the question of whether moving from the central planning system to a deregulated electricity market can materialize this objective still remains unexplored. Throughout the study, we focused on this issue by looking at the impact of reform steps on electricity industry efficiency. In the study, we used empirical econometric models to observe the impact of electricity market reform score on power sector efficiency. Panel data from 92 countries covering the period from 1982 to 2008 were employed. We found that reform process causes efficiency in the industry to go up but its effect is limited. Moreover, our findings showed that reform process has a negative impact on the efforts to reduce network losses.

It is obvious that present econometric evidence on the impact of the reform process is quite limited. So, there is a definite need for continued analyses of the effect of reforms in the electricity industry. Much work needs to be done and there are ample opportunities for research in this area. In many countries, power market reform is still an on-going process, a fact that also underlines the need for continued and up-to-date study. Besides, we admit that power market reform is complex and the evidence is difficult to evaluate. We also recognize that it is too early to reach any concrete judgment for future policy suggestions based on the results from this paper and other comparable studies. An exact calculation of the long-term effects of reforms on efficiency levels will require much additional study over longer periods of time.

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Appendices

Appendix 1: Estimation Results

Model No	Dependent variable	Explanatory variables	Coef.	Std. Err.	t-stat.	p-value	# of	# of	Hausman Test		BPLM Test		Preferred	Optimal # of reform steps
							countries	obs.	Stat.	p-value	Stat.	p-value	Specific.	
1.1	Log of plant load factor	Reform score	0.034	0.008	4.100	0.00	87	2,046	29.16	0.0000	-	-	Fixed Ef.	5
	(All countries)	Square of reform score	-0.006	0.001	-5.770	0.00								
		Log of GDP per capita	0.265	0.021	12.480	0.00								
		Constant	-1.344	0.031	-43.180	0.00								
1.2	Log of plant load factor	Reform score	0.043	0.006	6.690	0.00	32	771	87.96	0.0000	-	-	Fixed Ef.	7
	(Developed countries)	Square of reform score	-0.006	0.001	-7.340	0.00								
		Log of GDP per capita	0.157	0.017	9.440	0.00								
		Constant	-1.292	0.043	-29.910	0.00								
1.3	Log of plant load factor	Reform score	-0.106	0.077	-1.380	0.17	8	191	30.15	0.0000	-	-	Fixed Ef.	0
	(Developing countries in Africa)	Square of reform score	-0.009	0.014	-0.620	0.54								
		Log of GDP per capita	2.124	0.218	9.720	0.00								
		Constant	-0.968	0.063	-15.380	0.00								
1.4	Log of plant load factor	Reform score	0.026	0.014	1.760	0.08	18	468	73.11	0.0000	-	-	Fixed Ef.	8
	(Developing countries in America)	Square of reform score	-0.002	0.002	-1.080	0.28								
		Log of GDP per capita	0.120	0.037	3.220	0.00								
		Constant	-1.099	0.046	-23.710	0.00								
1.5	Log of plant load factor	Reform score	0.082	0.015	5.290	0.00	12	293	1.43	0.6979	899.83	0.0000	Random Ef.	8
	(Developing countries in Asia and Oceania)	Square of reform score	-0.009	0.002	-3.980	0.00								
		Log of GDP per capita	0.098	0.028	3.470	0.00								
		Constant	-0.989	0.048	-20.640	0.00								

1.6	Log of plant load factor *(Developing countries in Euro-Asia)*	Reform score	-0.066	0.014	-4.810	0.00	17	323	2.80	0.4232	1054.40	0.0000	Random Ef.	0
		Square of reform score	0.004	0.002	2.380	0.02								
		Log of GDP per capita	0.224	0.037	6.010	0.00								
		Constant	-1.177	0.084	-13.930	0.00								
2.1	Distance from optimal reserve margin *(All countries)*	Reform score	-0.038	0.009	-4.400	0.00	28	585	13.10	0.0044	-	-	Fixed Ef.	7
		Square of reform score	0.005	0.001	5.370	0.00								
		Log of GDP per capita	-0.141	0.028	-5.070	0.00								
		Constant	0.785	0.071	11.070	0.00								
2.2	Distance from optimal reserve margin *(Developed countries)*	Reform score	-0.032	0.009	-3.480	0.00	25	526	22.20	0.0001	-	-	Fixed Ef.	6
		Square of reform score	0.005	0.001	4.630	0.00								
		Log of GDP per capita	-0.176	0.031	-5.740	0.00								
		Constant	0.896	0.082	10.970	0.00								
2.3	Distance from optimal reserve margin *(Developing countries)*	Reform score	-0.119	0.031	-3.790	0.00	3	59	-	-	-	-	Fixed Ef.	8
		Square of reform score	0.012	0.003	3.890	0.00								
		Log of GDP per capita	0.092	0.074	1.250	0.22								
		Constant	0.309	0.107	2.890	0.01								
3.1	Electricity losses as a fraction of power generated *(All countries)*	Reform score	0.020	0.002	13.590	0.00	89	2,117	0.99	0.8033	9257.20	0.0000	Random Ef.	0
		Square of reform score	-0.002	0.000	-11.290	0.00								
		Log of GDP per capita	-0.041	0.003	-13.060	0.00								
		Constant	0.185	0.007	25.460	0.00								
3.2	Electricity losses as a fraction of power generated *(Developed countries)*	Reform score	0.001	0.001	2.140	0.03	32	793	15.86	0.0012	-	-	Fixed Ef.	0
		Square of reform score	0.000	0.000	-2.620	0.01								
		Log of GDP per capita	-0.011	0.002	-6.210	0.00								
		Constant	0.106	0.005	23.000	0.00								
3.3	Electricity losses as a fraction of power generated *(Developing countries in Africa)*	Reform score	0.049	0.008	6.020	0.00	9	218	0.02	0.9990	1331.39	0.0000	Random Ef.	0
		Square of reform score	-0.008	0.002	-5.450	0.00								
		Log of GDP per capita	-0.018	0.020	-0.870	0.39								
		Constant	0.134	0.032	4.160	0.00								
3.4	Electricity losses as a fraction of power generated *(Developing countries in America)*	Reform score	0.036	0.004	9.470	0.00	18	468	6.00	0.1118	1976.21	0.0000	Random Ef.	0
		Square of reform score	-0.004	0.001	-8.740	0.00								
		Log of GDP per capita	-0.044	0.009	-4.710	0.00								
		Constant	0.205	0.017	12.050	0.00								

3.5	Electricity losses as a fraction of power generated *(Developing countries in Asia and Oceania)*	Reform score	-0.009	0.005	-1.760	0.08	12	293	4.40	0.2210	667.67	0.0000	Random Ef.	4
		Square of reform score	0.002	0.001	2.460	0.01								
		Log of GDP per capita	-0.036	0.009	-3.930	0.00								
		Constant	0.183	0.013	13.970	0.00								
3.6	Electricity losses as a fraction of power generated *(Developing countries in Euro-Asia)*	Reform score	0.043	0.005	8.830	0.00	18	345	4.93	0.1773	558.77	0.0000	Random Ef.	0
		Square of reform score	-0.005	0.001	-6.940	0.00								
		Log of GDP per capita	-0.060	0.011	-5.400	0.00								
		Constant	0.217	0.019	11.450	0.00								
4	Log of net generation per employee in elec. ind. *(Developed countries)*	Reform score	0.022	0.004	5.370	0.00	17	322	0.25	0.8807	2247.70	0.0000	Random Ef.	8
		Log of GDP per capita	0.785	0.035	22.360	0.00								
		Constant	-1.392	0.156	-8.910	0.00								
5.1	Log of net generation per employee in utility ind. *(All countries)*	Reform score	0.019	0.004	4.410	0.00	60	1,011	6.68	0.0355	-	-	Fixed Ef.	8
		Log of GDP per capita	0.581	0.033	17.800	0.00								
		Constant	-1.296	0.067	-19.320	0.00								
5.2	Log of net generation per employee in utility ind. *(Developed countries)*	Reform score	0.024	0.004	6.890	0.00	32	645	2.73	0.2557	4600.53	0.0000	Random Ef.	8
		Log of GDP per capita	0.642	0.028	22.920	0.00								
		Constant	-1.441	0.129	-11.130	0.00								
5.3	Log of net generation per employee in utility ind. *(Developing countries in America)*	Reform score	0.116	0.037	3.120	0.00	14	166	1.65	0.6479	267.10	0.0000	Random Ef.	6
		Square of reform score	-0.018	0.005	-3.310	0.00								
		Log of GDP per capita	0.545	0.088	6.160	0.00								
		Constant	-1.442	0.149	-9.700	0.00								
5.4	Log of net generation per employee in utility ind. *(Developing countries in Asia and Oceania)*	Reform score	-0.078	0.069	-1.130	0.26	8	124	46.30	0.0000	-	-	Fixed Ef.	0
		Square of reform score	0.023	0.012	1.910	0.06								
		Log of GDP per capita	0.708	0.137	5.150	0.00								
		Constant	-1.717	0.058	-29.360	0.00								
5.5	Log of net generation per employee in utility ind. *(Developing countries in Euro-Asia)*	Reform score	-0.228	0.045	-5.070	0.00	5	75	8.55	0.0359	-	-	Fixed Ef.	0
		Square of reform score	0.031	0.004	6.890	0.00								
		Log of GDP per capita	-0.192	0.159	-1.210	0.23								
		Constant	0.180	0.237	0.760	0.45								