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New evidence on the impact of structural reforms on electricity sector performance

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HIGHLIGHTS

- We assess the impact of structural reforms on OECD electricity sector performance.
- Regulation has stronger impact on performance when interaction terms are present.
- Privatisation has unambiguous effect on the elements of performance.
- The combined effect of reforms on performance is more aggressive in the long run.

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ABSTRACT

The evolution of electricity industry over the last decades has shown substantial differences between OECD countries. This paper empirically investigates to what extent different structural forms of regulation, competition and privatisation explain these international differences. It distinguishes three modes of electricity performance: a) net generation per capita, b) installed capacity and c) labour productivity. The empirical model spans the period 1975–2011 and uses panel data econometric techniques. Our analysis reveals that there is a strongly significant interaction impact on the level of electricity performance between regulation and competition. The empirical findings do confirm that a robust independent regulatory scheme must be implemented in order to achieve a competitive electricity market.

1. Introduction

After prolonged periods of structural immobility in the electricity industry, during the past two-and-a-half decades, governments have been allowing market forces to play an increasing role in the sector. Indeed, in recent years, structural change in the electricity industry became a global phenomenon (Pollitt, 2009; Fafaliou and Polemis, 2010). A large number of countries have introduced a combination of institutional reforms (i.e competitive restructuring, regulatory reform, creation of regulatory institutions, and privatisation, etc). It has been difficult so far to get a clear picture of reform results for various reasons. First, countries have implemented electricity sector reforms in varying ways and degrees. Second, crucial economic variables are marred by severe measurement problems, especially in developing and transition economies and lastly privatisation and regulatory reform have usually been implemented simultaneously making it very difficult to quantify their separate effects.

This paper investigates to what extent structural reforms affect electricity sector performance for 30 OECD countries over the period 1975–2011. In particular, using two different econometric methodologies for panel data, such as a static fixed effects procedure and a dynamic GMM approach, employed by Arellano and Bond (1991), this study aims to identify the effects of regulation, competition and privatisation on the performance of the industry. Unlike previous studies, this research tries to explore the difference between separate and joint effects among these structural reform variables, in the concept of a static model as well as the

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difference between short run and long run effects in the concept of a dynamic model. The objective is to capture the separate effects that these main drivers of electricity performance have for OECD countries as well as how they contribute to the design of better regulatory reform programs.

This paper contributes the literature in many ways. Firstly, unlike previous studies (Zhang et al., 2002; Cubbin and Stern, 2006; Zhang et al., 2008; Erdogdu, 2011), devoted on this topic we try to assess the linkage and the possible spillover effects between regulation, competition and privatisation and the level of electricity performance by using superior measures of the effectiveness of regulation and competition. For this reason, we use the most up to date regulation and competition indices provided by the OECD. Secondly, this is the first study we use the regulation components of the Fraser Index of Economic Freedom to examine the impact of credit (financial), labour and business regulation, on electricity performance in the 30 OECD sample countries. The use of the FRASER index, allows greater insight into this issue and this is one of the novelties of this paper. Thirdly, it goes beyond the existing literature in that it combines static and dynamic panel data econometric techniques, in which rather scant attention has peen paid by the earlier studies (Fiorio et al., 2007; Zhang et al., 2008). It is worth mentioning that the combined use of static and dynamic interactions between the variables of our models will also test for the robustness of our findings.

The rest of the paper is organized as follows. Section 2 reviews the empirical literature, while Section 3 presents the methodology used in the empirical analysis. Section 4 reports the main empirical findings of the paper. Lastly, Section 5 concludes the paper and provides some policy implications.

2. Review of the literature

From the empirical stand point, it is interesting to highlight that many researchers have attempted to study and analyse several aspects of the electricity sector. At the macroeconomic level an effort is made to examine economic growth with respect to the level of electricity intensity, including issues of causality (see, for example, Hondroyiannis et al., 2002; Narayan and Smyth, 2007; Lee and Chang, 2008; Payne, 2010; Ozturk, 2010; Tang and Tan, 2012; Polemis and Dagoumas, 2013). Some other researchers have analysed microeconomics aspects of the electricity sector mainly by estimating price elasticities among other things (Maddala et al., 1997; Bernstein and Graffin, 2005; Polemis, 2006, 2007; Fell et al., 2014). Beyond of all these perspectives, several other studies have investigated the impact of structural reform policies regarding regulation, competition and privatisation on the overall performance of the electricity sector.

Earlier studies highlight the importance of political and institutional variables (i.e level of taxation, FDI influx, corruption in the public sector, etc) in determining the pace of reform and the investment activity in the electricity industry (see for example Henisz, 2000; Bacon and Besant-Jones, 2001). Most of these studies use panel data econometric methodology (fixed effects and GMM estimators) and focus on the developing countries while others examine the impact of these indicators on more liberalised regimes (i.e European countries).

We must stress however, that the majority of the empirical studies are devoted in the assessment of the effect of structural reform variables such as regulation, competition and privatisation on the level of electricity performance. Two pioneering studies consent that effective regulation followed by the opening of the markets to competition increases electricity performance (Bortolotti, et al., 1998; Steiner, 2001). This empirical finding can also be confirmed by more recent studies (see for example Zhang et al., 2002, 2005; Cubbin and Stern, 2006; Fiorio et al. 2007; Zhang et al., 2008, Erdogdu, 2011; Pompei, 2013). In a recent interesting study, Davis and Wolfram (2012) examine the effects of deregulation on the US nuclear electricity generation industry, and critically discuss the interaction between privatisation and regulation. More specifically, they analyse operating efficiency before, during, and after market restructuring and conclude that deregulation and consolidation are associated with a 10% increase in operating efficiency. These results provide clear evidence of efficiency gains from the deregulation of electricity markets since removing regulation has provided incentives for firms to increase efficiency, reduce costly outages, and make prudent investments in capacity.

All of these studies use a variety of indicators (i.e dummy variables, constructed indices) in order to quantify the level of structural reforms in the electricity industry. However, they neglect to account for the effect of these reforms on the level of prices in the sector. This gap has been filled within the last decade by some empirical studies (Hattori and Tsutsui, 2004; Fiorio and Florio, 2013). Specifically, Hattori and Tsutsui (2004), find that expanded retail access is likely to lower the industrial price and increase the price differential between industrial customers and household customers. They also claim that the unbundling of generation and the introduction of a wholesale spot market did not necessarily lower the price and may possibly have resulted in a higher price. Similarly, Fiorio and Florio (2013), assess the impact of corporate ownership on residential net-of-tax electricity prices, when the ownership effect is separated from the liberalisation effect and from other drivers of change. They use IEA and OECD data for the EU-15 over nearly three decades. Panel econometrics suggests that, after controlling for other factors, public ownership is associated with lower residential net-of-tax electricity prices in Western Europe. However, the impact of liberalisation on prices is smaller and more uncertain.

In contrast to the related studies, that use partial equilibrium models, Akkemik and Oguz (2011) make use of applied computable general equilibrium model in order to examine the competitive conditions in the Turkish electricity industry. They argue that regulatory reforms have led to the enhanced efficiency in the electricity sector, reduced household energy prices, and gains in output and welfare. Moreover, with changing institutional background and legal framework, political pressures tend to dominate efficiency gains.

Overall, the available empirical evidence suggests that in assessing the results of electricity privatisation in various countries the effects of competition and regulation also need to be taken into account. However, the empirical literature is still in its infancy since most of the reported studies have tended to look at only one or maybe two of these three reforms without controlling for the others neglecting possible interaction effects. Further, one of the main weaknesses of the empirical studies on this issue is that serious problems related to measurement and specification choice have not permitted a definitive and defensible structural interpretation of results. The absence of tight specification along with the existence of competing structural explanations for the findings of most of these studies is a reason why this line of research has not been able to provide a convincing assessment of the electricity reform outcomes.

3. Data and methodology

We use an unbalanced panel data set for 30 OECD countries over the period from 1975 to 2011.[1] The model employed in this

[1] The sample countries are the following: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States.

study follows the specification of Zhang et al. (2008). However, we extend this analysis in several ways. First, the regulation indicator in Zhang et al. (2008) is based on the construction of a four-component index (existence of electricity/energy law, regulatory independence, fixed-term appointment for the head of the regulatory body and type of finance of the regulator). The problem with this measure as stated in Zhang et al. (2008) is that there is limited published information on the forms of regulation adopted in particular developing countries. We deal with this issue by using a superior measure of actual regulation (Regulatory Reform Index or RRI), published by the OECD which shows high reliability (Pompei, 2013). This indicator is built by means of a bottom-up approach based on information about existing laws and regulations and guarantees a high level of comparability across the surveyed countries (Conway and Nicoletti, 2006).

Second, the competition indicator in Zhang et al. (2008) is constructed on the basis of the market share of the three largest generators in the sector (CR-3). The problem with this measure is that in network industries like electricity, this proxy may exaggerate the extent of market competition. Furthermore, it gives limited information on the market structure of an industry since it accounts only for the three largest market players by ignoring the others and the relevant distribution of their market shares. In order to effectively tackle with this constraint, we rely on the information of the market structure (oligopoly, competition) of the electricity industry in the sample countries as measured by the two dummy variables (WHOL and TPA) published by the OECD. The dummy variable WHOL measures the existence of a liberalised wholesale market for electricity. More specifically, it takes the value of one if a wholesale pool is existing, whilst is set to zero. Similarly, the other indicator (TPA) accounts for the third party access to the electricity transmission grid within the sample countries. It takes the value of zero if TPA is absent otherwise is set to one.

Similarly to the aforementioned model, all non-index and non-percentage variables used in the paper took the log form. More specifically, the reduced form equation is the following:

$$Y = a_0 + a_1X + a_2Z + n_i + u_t + \varepsilon_{it} \tag{1}$$

Where $Y = \begin{bmatrix} GEN_{it} \\ CAP_{it} \\ LAB_{it} \end{bmatrix}$ denotes the vector of the three dependent variables accounting for the generation (GEN_{it}), capacity utilization (CAP_{it}) and labour efficiency (LAB_{it})in the electricity industry respectively. $X = \begin{bmatrix} PRIV_{it} \\ WHOL_{it} \\ TPA_{it} \\ RRI_{it} \end{bmatrix}$ represents the vector of the structural reform variables accounting for the impact of privitization ($PRIV_{it}$), competition ($WHOL_{it}$ and TPA_{it}) and regulation (RRI_{it}) on the electricity performance respectively. Lastly, Z denotes the vector of the other covariates including the time trend. Table A1 in the Appendix A, provides a complete description of the variables included in this study.[2] Moreover, a_o is the constant term, n_i is the unit-specific residual that differs between countries but remains constant for any particular country (unobserved country level effect), u_t captures the time effect and therefore differs across years but is constant for all countries in a particular year and finally ε_{it} stands for the idiosyncratic disturbance term (i.i.d). Table A2, reports a complete set of summary statistics for all the variables used in the econometric analysis. From the relevant table, it is evident that the sample data are well behaved showing limited variability in relation to the mean of the population, since the values of the coefficient of variation measure are close to zero. By contrast, the variables are not normally distributed, since the relative values of the skewness and kurtosis measures are not zero and three respectively.

It is worth mentioning that previous studies have tended to look at only one or maybe two of the reforms without controlling for the others and considering possible interaction effects. For this study an original data set was created that allowed for the measure of these separate effects and their possible interactions. The main reason for incorporating these interactions is that we want to test if some or all of the three key reform variables (privatisation, competition and regulation) are jointly determined. As argued by Wallsten et al. (2004), regulations, regulators, regulated industries, and politics interact in complicated ways that affect the development of the industry as well as the rest of the economy. It is worth mentioning that, the importance of these interactions has long been recognized and debated in many countries especially in the United States and the UK (see for example Baron, 1989, Braeutigam, 1989, Noll, 1989, Peltzman, 1976, Stigler, 1971).

Further, the empirical literature has pointed out that although some of the reform variables are not significant separately, when are considered together have a statistically significant impact on the dependent variables (Wallsten, 2001; Zhang et al., 2008). In line with the findings of the empirical literature, it is interesting to study if such interaction effects are present between the key reform variables from a policy perspective. In other words, investors, policy makers and government officials (i.e ministries, regulatory bodies, competition authorities, etc) will be greatly benefited from the assessment of these interaction effects in order to implement their policy goals. To be more specific it is often argued that Independent Power Producers (IPPs) who are willing to invest, feel their investment less risky when there is an independent regulator instead of direct government control of the sector (Zhang et al., 2008). Therefore the interaction effect between regulation and privatisation (R*P) will be stronger than its independent counterpart.

To explore possible interaction effects, we incorporate the vector V in the following model:

$$Y = a_0 + a_1X + a_2X^*V + a_3Z + n_i + u_t + \varepsilon_{it} \tag{2}$$

where V is a vector of the interacted structural reform variables (PRIV, WHOL, TPA and RRI). The above equations are estimated by allowing fixed effects as a baseline. Given the nature of the underlying model, we would expect a fixed effects model to be more appropriate than a random effects model. This could be attributed to the fact that the fixed effects static model avoids the potential biases which could arise in the random effects model owing to correlation between the included exogenous variables and omitted country attributes (Cubbin and Stern, 2006). However, we tested this assumption using the Hausman test and the random effects model was consistently rejected in favour of a fixed effects model.[3] In order to check for the robustness of our findings and deal with possible endogeneity issues we re-estimate the relevant equations by employing dynamic panel data techniques. To overcome this problem, we utilize two dynamic GMM estimators developed by Arellano and Bond (1991) and Blundell and Bond (1998) respectively. The former estimator is also known as a two-step difference GMM (DIF-GMM) where the lagged levels of the regressors are instruments for the equations in first differences. The latter

[2] Due to the lack of sufficient comparable data across the sample countries, we could not incorporate in our analysis other electricity performance indicators such as the quality of service and the reforms on the prices charged for electricity generated.

[3] The results are available upon request.

(System GMM) combines the regression expressed in first differences with the original equation expressed in levels and allows us to include some additional instrument variables (Arellano and Bover, 1995). The main advantage of having a time lag of the dependent variable as independent variable is to capture short run and long run effects that cannot be identified by a static model.

4. Empirical findings

In this section, we present our empirical findings from the estimation of the static and dynamic panel data analysis respectively. The models were estimated incorporating corrections for autocorrelated errors within cross-sectional units.

4.1. Static model results

Nine different models are estimated for the period 1975–2011 allowing for fixed effects (See Table 1). In the models 1–3 the dependent variable is the net generating electricity per capita (GEN). Models 4–6 explore the possible interactions between the installed electricity capacity (CAP) as the dependent variable and its main regressors, while models 7 to 9 capture the main drivers of the labour productivity in the electricity sector (LAB). It is noteworthy that models 2, 3, 5, 6, 8 and 9 include the possible interactions between the main electricity performance variables (PRIV, RRI, TPA and WHOL).

Table 1 contains the estimation results of the static model employed. It is evident that the coefficients are statistically significant, the signs are the expected ones and the fit is substantially high. The high value of the adjusted R-squared is an indication that the control variables might be correlated thus, resulting in numerically unstable estimates of the regression coefficients (multicolinearity). In order to investigate the existence of multicolinearity, we build the correlation matrix of the independent variables (see Table A2 of the Appendix A) and accordingly estimate the variance inflation factors (VIF) generated by the three equations.[4] From the relevant table we conclude that the control variables are not correlated and most importantly the VIF for the three reduced form equations are negligible.[5]

In terms of the structural control variables, regulation (RRI) as measured by the OECD regulatory reform index is found to be statistically significant in four out of nine specifications (models 2, 3, 4 and 8). This result indicates that a better regulatory environment in the electricity sector is definitely associated with the increase of the electricity performance (GEN, CAP and LAB). The sign of this variable is negative revealing that an increase in the relevant index, meaning that the regulatory environment in the OECD countries is getting worse, leads to a reduction in the level of net generation (GEN) and installed capacity (CAP) in the electricity sector, which in turns, lowers the labour productivity level (LAB). Similarly, a decrease in the RRI, by implementing effective regulatory measures in the OECD countries, is related to an increase in the electricity performance. The relevant coefficient when significant lies within the range of -0.001 to -0.041. This means that a 100% increase in the level of electricity regulation (e.g network unbundling, liquid power exchanges, further market opening, etc) which leads to a decrease in the level of the regulatory index, portrays an increase in the level of electricity performance indicators ranging from 0.1% to 4.1%.

The statistically significant impact of regulation on the level of electricity performance, clearly states that a well-defined regulatory framework can be expected to reduce ‘regulatory risk’ and provide incentives for private investment which in turns leads to an increase in the level of installed electricity capacity. In other words, imposing an independent regulator where state ownership persists seems to be effective. This finding contradicts the study of Zhang et al. (2008) in which the coefficient of the regulation variable is statistically insignificant. This could be attributed to the different methodology applied in estimating the regulatory index.

Privatisation in the electricity sector is negatively associated with electricity performance activity, since in all of the specifications the relevant coefficients are negative and in some cases statistically insignificant (models 1, 2 and 9). This means that the transfer of the ownership of the vertically integrated state-owned utilities into a more competitive and privatised schemes decreases or leaves unaffected the electricity performance. This finding is in alignment with similar studies (Cubbin and Stern, 2006; Zhang et al., 2008; Pompei, 2013; Fiorio and Florio, 2013), which is argued that possibly privatisation would lead to lower output, at least in the short-run. This finding which is also consistent with the severe problems revealed by underinvestment in the UK electricity sector and the debate surrounding the British government's White Paper (DECC, 2011; Del Bo and Florio, 2012), can be confirmed in the next section, where we distinguish between short-run and long-run effects of the privatisation variable on the electricity performance.

The discussion now turns to the various competition variables. More specifically, competition in the electricity sector as expressed by its proxy dummy variable (WHOL) showing the presence of a liberalised wholesale market seems to positively affect the electricity performance variables since the relevant coefficients are statistically significant in nearly all of the models. The relevant coefficient when significant lies within the range of 0.026–0.161. This finding suggests that a more equal division of the market between electricity generators leads to a higher level of electricity performance. Similarly, the dummy variable representing the terms and conditions of third party access to the electricity transmission grid (TPA) does affect the level of electricity performance since the relevant coefficients in all of the specifications are positive and statistically significant. With respect to their magnitude it is interesting to note that the existence of third party access to the transmission grid (TPA) has larger impact on the three performance indicators than the presence of a liberalised wholesale market (WHOL). Further, it is evident that competition has the largest coefficient of any of the reforms (regulation and privatisation). As a consequence, we argue that competition is an effective driver of electricity performance.

These results are in alignment with the existing literature confirming the existence of a statistically significant relationship between the competition proxy variables in the electricity industry and the level of its performance (Zhang et al., 2005, 2008, Akkemik and Oguz, 2011).

Regarding the interaction terms between privatisation and competition (PRIV*TPA and PRIV*WHOL) it is noteworthy that when significant are surprisingly negatively associated with the electricity performance in nearly all of the models (except model 9). On the other hand the positive and statistically significant coefficient of the interaction term between PRIV*TPA (0.036) indicates that in markets with third party transmission grid access, privatisation increases labour productivity. Taken this together, we conclude that it is competition on its own rather than competition and ownership change that is crucial in explaining increased

[4] Variance inflation factors are used to detect multicolinearity. VIF are a scaled version of the multiple correlation coefficients between variable j and the rest of the independent variables. Specifically, $VIF_j = \frac{1}{1-R_j^2}$, where R_j is the multiple correlation coefficient. If R_j equals zero (i.e., no correlation between X_j and the remaining independent variables), then VIF_j equals 1. This is the minimum value. A value greater than 10 is an indication of potential multicolinearity problems (Neter et al., 1990).

[5] Due to space limitations, the results of the VIFs are available upon request.

Table 1
Static panel fixed effects results.

Variables	(1) GEN	(2) GEN	(3) GEN	(4) CAP	(5) CAP	(6) CAP	(7) LAB	(8) LAB	(9) LAB
lnGDP	0.406*** (0.035)	0.427*** (0.034)	0.406*** (0.034)	0.074* (0.039)	0.076** (0.038)	0.073** (0.038)	0.730*** (0.015)	0.724*** (0.015)	0.718*** (0.015)
PRIV	−0.014 (0.014)	−0.002 (0.018)	−0.033** (0.018)	−0.060*** (0.017)	−0.095*** (0.022)	−0.095*** (0.023)	−0.016** (0.007)	−0.008*** (0.008)	0.0001 (0.008)
RRI	−0.002 (0.005)	−0.041*** (0.010)	−0.018*** (0.005)	−0.012** (0.005)	−0.010 (0.009)	−0.002 (0.005)	−0.001 (0.002)	−0.001*** (0.002)	−0.0002 (0.002)
TPA	0.024** (0.011)	–	0.570*** (0.082)	0.059*** (0.012)	–	0.217*** (0.066)	−0.010* (0.006)	–	0.023 (0.018)
WHOL	0.066*** (0.014)	0.161*** (0.033)	–	0.029** (0.012)	0.033 (0.032)	–	−0.008 (0.006)	0.026** (0.013)	–
EXPORT	−0.0001 (0.001)	−0.0003 (0.001)	0.0002 (0.001)	−0.002*** (0.000)	−0.002*** (0.000)	−0.002*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001 (0.000)
FRASER	0.087*** (0.005)	0.074*** (0.006)	0.067*** (0.007)	0.038*** (0.008)	0.022*** (0.009)	0.017* (0.010)	0.033*** (0.004)	0.033*** (0.004)	0.034*** (0.004)
IND	0.007*** (0.001)	0.005*** (0.001)	0.006*** (0.001)	0.004*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.001 (0.001)	0.001*** (0.001)	0.001** (0.001)
URBAN	0.038*** (0.002)	0.039*** (0.002)	0.037*** (0.001)	0.029*** (0.002)	0.030*** (0.002)	0.027*** (0.002)	0.001** (0.001)	0.001*** (0.001)	0.001*** (0.000)
TREND	0.010*** (0.001)	0.010*** (0.001)	0.010*** (0.001)	0.014*** (0.001)	0.015*** (0.001)	0.015*** (0.001)	0.001*** (0.000)	0.001*** (0.000)	0.001** (0.000)
PRIV x RRI	–	0.010 (0.009)	0.039*** (0.008)	–	0.027*** (0.008)	0.029*** (0.007)	–	0.0008*** (0.004)	−0.023*** (0.005)
PRIV x TPA	–	–	−0.116*** (0.020)	–	–	−0.039** (0.019)	–	–	0.036*** (0.013)
PRIV x WHOL	–	0.036 (0.022)	–	–	−0.007 (0.025)	–	–	−0.029*** (0.014)	–
RRI x WHOL	–	−0.048*** (0.012)	–	–	−0.0004 (0.010)	–	–	−0.008*** (0.004)	–
RRI x TPA	–	–	−0.067*** (0.010)	–	–	−0.027*** (0.010)	–	–	−0.004 (0.004)
TPA x WHOL	–	0.024** (0.011)	−0.209*** (0.068)	–	0.043*** (0.013)	−0.034 (0.036)	–	−0.005*** (0.007)	−0.020* (0.010)
Constant	17.270*** (0.014)	17.078*** (0.305)	17.495*** (0.311)	−0.311 (0.454)	−0.266 (0.441)	−0.051 (0.446)	3.296*** (0.123)	3.356*** (0.123)	3.396*** (0.124)
Diagnostics									
Observations	962	962	962	834	834	834	962	962	962
Number of countries	29	29	29	29	29	29	29	29	29
Adjusted R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
Standard error of regression	0.18	0.18	0.17	0.12	0.12	0.12	0.06	0.05	0.06
F-statistic	13154.37*** [0.00]	13331.83*** [0.00]	14370.15*** [0.00]	11205.00*** [0.00]	10609.52*** [0.00]	10618.84*** [0.00]	1870.30*** [0.00]	1754.21*** [0.00]	1755.03*** [0.00]
LR	2.17 [0.42]	1.78 [0.12]	2.82 [0.23]	1.30 [0.41]	1.33 [0.49]	1.14 [0.13]	2.14 [0.17]	1.15 [0.21]	1.17 [0.34]
W-T	2.17 [0.30]	1.82 [0.45]	3.86 [0.28]	1.29 [0.24]	2.27 [0.32]	1.15 [0.19]	3.52 [0.22]	1.52 [0.28]	1.22 [0.45]

Note: the use of the fixed effects specification is justified after a Hausman test for each model. Robust standard errors are in parentheses. The numbers in square brackets are the *p*-values. LR denotes the Likelihood Ratio test for the presence of heteroscedasticity. W-T is the Wooldridge *F*-test for autocorrelation in the error term.

*** Significant at 1% respectively.
** Significant at 5% respectively.
* Significant at 10% respectively.

electricity output and installed capacity in our sample (Zhang et al., 2008).

In contrast, privatisation and regulation have shown a positive and statistically significant interaction. The positive sign indicates that the establishment of a sound effective regulatory framework enhances the investors' interests leading to an increased electricity performance. Finally the results for the interaction of regulation and competition (RRI*WHOL and RRI*TPA) are also robust between the estimated models in finding a negative and statistically significant impact on electricity performance. This finding implies that a better regulatory environment in the electricity sector which is associated with lower values of the RRI index positively interacts with competition, increasing the level of electricity performance as measured by the three alternative indicators.

In terms of the macroeconomic variables entered the models (GDP, IND, URBAN, EXPORT), it is worth mentioning that most of their coefficients are statistically significant and plausible signed. The economic risk variable (FRASER), has a positive and statistically significant impact on electricity performance implying that countries with lower economic risk seem to be associated with higher electricity performance (Zhang et al., 2008). Lastly, the coefficient of the time trend (TREND) has the correct positive sign and is statistically significant in all of the estimated models, denoting that technological development boosts electricity performance as expressed by its three indicators (GEN, CAP and LAB).[6]

Moreover, the estimated equations appear to be well behaved to the diagnostic tests. The adjusted R-square is significantly high denoting that variation in the dependent variable is well captured by variations in the explanatory variables. In addition, in all nine specifications according to Hausman test, the hypothesis of zero random effects can not be rejected at a very high significance level (p-value $<1\%$), thus indicating the validity of the fixed effects estimator.[7] Moreover, the F-statistic of the joint significance of all the explanatory variables is rejected at the 1% level in all of the nine models indicating the validity of the specified control variables. Lastly, the LR and W-T diagnostic tests denote the absence of heteroscedasticity and autocorrelation revealing that the error terms in all of the nine specifications are i.i.d.

However, we must be aware that potential endogeneity may be present in the case of a privatisation process in the electricity industry. This will occur when the public utilities are problematic and the government decides to take the radical step of privatising them. Because of this, an OLS estimator would tend to underestimate the effect of the structural reform variables (i.e privitization) on electricity generation, capacity utilization and labour efficiency respectively (coefficient biased towards zero). The latter can be a problem because, if unobserved variables jointly affect both the dependent and control variables, then the coefficient estimates for the independent variables may be biased (Hausman and Ros, 2003). For this reason we utilize a dynamic two-step GMM estimator developed in the next section (Arellano and Bond, 1991). This estimator takes into account the unobserved time-invariant bilateral specific effects, and the country-specific factors to be filtered out while it can deal with the potential endogeneity arising from the inclusion of several control variables such as privatisation.

4.2. Dynamic model results

To avoid generating spurious results due to the presence of unit roots, all the variables of the models were first examined for stationarity and transformed by differencing if needed. Given the relatively short span of the time series element ($T=36$), all the commonly used unit root tests (Augmented Dickey –Fuller, Phillips-Perron and KPSS tests) separately to each country may have low power, (Christopoulos and Tsionas, 2003). Thus our results for the stationarity properties of the data could be seriously misguided. An increase in the power of individual unit root tests can be achieved by pooling individual time series and performing panel unit root tests.

To test for the existence of a unit root in a panel data setting (test for integration), we have used various classical econometric tests (Harris and Tzavalis, 1999, Im, Pesaran and Shin W-test, Fisher type tests, Levin, Lin and Chu-t test, Hadri test). Applying the relevant tests, we observe that the null-hypothesis of a unit root cannot be rejected at 5% critical value for all of the relevant variables (see Appendix A – Table A3). In other words all the control variables are integrated of order one I(1) including in some cases deterministic components (intercept or trend).

In the next stage, panel cointegration tests (see Appendix A-Table A4) are used in order to draw sharper inferences since time spans of economic time series are typically short. In order to investigate the existence of one or more cointegrated vectors we apply several tests (Hsiao, 1986; Kao, 1999). From the relevant table it is evident that the null hypothesis of no cointegration is rejected at 1% level according to the employed cointegration tests. More specifically, by employing the Fisher test, it is evident that there is one cointegrating vector at the 5% level.

Table 2 reports the estimates of the DIF-GMM models. As it may be seen, the empirical evidence in favour of the electricity regulatory effect on the electricity performance does not change when employing dynamic panel analysis. This result shows that the liberalisation of the electricity sector in the OECD countries is a significant prerequisite for the enhancement of its performance. The relevant finding is in alignment with some of the empirical studies (see for example Cubbin and Stern, 2006; Pompei, 2013) in which there is clear evidence that better regulatory governance is a statistically significant determinant of generation capacity utilisation. More specifically, the estimated coefficients of the regulatory index are negative ranging from -0.002 to -0.059 and statistically significant different from zero at the 5% level in nearly all of the models (see models 1, 2, 3, 6 and 8). This means that, in the long-run, each unit decrease in the electricity regulatory index increases labour productivity (LAB) and per capita net generating electricity (GEN) by 0.2% and 5.9% respectively. In other words, a country with the worst regulatory electricity environment and an index score of 6 could expect to have 1.2% and 35.4% lower labour productivity and electricity generation respectively (Pompei, 2013).

It is interesting to highlight that privatisation (PRIV) is negatively and in most cases statistically insignificant associated with the level of electricity performance. Similarly, with the static model results, and in alignment with other studies reported previously, we failed to find any positive relationship between the privatisation and the three main measurements of electricity performance. More specifically, the reform dummy variable (PRIV), is significantly negatively correlated with the employment efficiency measure. This may indicate that firms begin to increase labour efficiency once reform legislation is passed, to prepare for upcoming market changes such as the increase in the sale price. Additionally, the lagged electricity performance indicators are significant at the 1% level and their high magnitude implies the suitability of the dynamic panel data estimation.

Turning to the effects of competition among generators, we found to be positively associated with electricity generation per capita (GEN) and labour productivity (LAB). This finding coincides with the economic theory and the empirical literature, suggesting

[6] When we include the squared time trend, the estimated coefficient is found to be statistically significant and negative, showing that electricity performance is growing over time, but at a decreasing rate.

[7] The results are available upon request.

Table 2
Dynamic panel DIF-GMM results.

Variables	**(1) GEN**	**(2) GEN**	**(3) GEN**	**(4) CAP**	**(5) CAP**	**(6) CAP**	**(7) LAB**	**(8) LAB**	**(9) LAB**
lnGEN (-1)	0.331* (0.183)	0.362*** (0.063)	0.222 (0.231)	–	–	–	–	–	–
lnCAP (-1)	–	–	–	0.216* (0.152)	0.423* (0.280)	0.129* (0.068)	–	–	–
lnCAP (-2)	–	–	–	0.784*** (0.221)	−0.151 (0.274)	−0.196** (0.101)	–	–	–
lnLAB (-1)	–	–	–	–	–	–	0.563*** (0.041)	−0.280*** (0.027)	−0.286*** (0.025)
lnLAB(-2)	–	–	–	–	–	–	−0.268*** (0.040)	−0.250*** (0.060)	−0.277*** (0.061)
ln(GDP)	0.378*** (0.093)	0.392*** (0.046)	0.278*** (0.105)	0.060* (0.033)	0.115** (0.049)	0.113*** (0.038)	0.600*** (0.012)	0.673*** (0.025)	0.677*** (0.026)
PRIV	−0.033 (0.041)	0.038 (0.181)	−0.472* (0.307)	−0.022* (0.013)	0.167 (0.157)	0.062 (0.042)	−0.013*** (0.003)	−0.216*** (0.040)	−0.147*** (0.028)
RRI	−0.021** (0.009)	−0.058** (0.026)	−0.059** (0.034)	−0.004* (0.003)	0.001 (0.032)	−0.016** (0.007)	−0.002* (0.001)	−0.013** (0.007)	−0.011* (0.006)
TPA	0.022* (0.017)	–	−0.684* (0.507)	0.008 (0.008)	–	0.045 (0.095)	0.003*** (0.001)	–	0.124 (0.058)
WHOL	0.022* (0.018)	0.171* (0.096)	–	−0.006 (0.008)	−0.090 (0.102)	–	0.006*** (0.002)	−0.007 (0.025)	–
EXPORT	−0.001 (0.001)	−0.0002 (0.000)	−0.002** (0.001)	−0.001** (0.001)	−0.001** (0.000)	−0.001* (0.000)	0.0005*** (0.000)	0.0004** (0.000)	0.0004** (0.000)
FRASER	−0.008 (0.013)	−0.015 (0.011)	−0.005 (0.015)	0.008 (0.007)	−0.001 (0.008)	0.017** (0.007)	−0.004** (0.002)	0.0001 (0.002)	0.0007 (0.002)
IND	0.005*** (0.002)	0.005*** (0.001)	0.006*** (0.002)	0.002** (0.001)	0.001 (0.001)	−0.0003 (0.001)	0.001** (0.000)	0.002*** (0.000)	0.002** (0.000)
URBAN	0.013*** (0.005)	0.014*** (0.004)	0.015** (0.006)	−0.004 (0.009)	0.016* (0.009)	0.026*** (0.008)	0.001 (0.001)	−0.001 (0.002)	0.0004 (0.003)
TREND	0.009*** (0.004)	0.008*** (0.002)	0.015** (0.007)	−0.0003 (0.006)	0.010* (0.005)	0.011*** (0.004)	0.0007 (0.001)	0.015*** (0.002)	0.014*** (0.003)
PRIV x RRI	–	0.043 (0.110)	0.205 (0.143)	–	−0.179* (0.112)	−0.028** (0.013)	–	0.088*** (0.025)	0.050*** (0.010)
PRIV x TPA	–	–	0.401 (0.868)	–	–	0.190 (0.144)	–	–	0.003 (0.117)
PRIV x WHOL	–	−0.127* (0.075)	–	–	0.256** (0.120)	–	–	−0.035* (0.024)	–
RRI x WHOL	–	−0.067** (0.031)	–	–	0.020 (0.036)	–	–	0.004 (0.008)	–
RRI x TPA	–	–	0.135 (0.098)	–	–	−0.018 (0.017)	–	–	−0.018 (0.012)
TPA x WHOL	–	–	–	–	–	–	–	–	–
Diagnostics									
Observations	904	875	875	748	747	689	866	846	846
Number of countries	30	30	30	30	30	30	30	30	30
Standard error of regression	0.074	0.074	0.082	0.042	0.041	0.039	0.021	0.022	0.023
Instrument rank	19	25	25	19	24	29	28	29	29
Sargan-Hansen test	23.193 [0.312]	18.554 [0.110]	11.180 [0.513]	5.659 [0.580]	28.060 [0.263]	16.838 [0.328]	15.061 [0.520]	11.465 [0.719]	13.304 [0.578]
AR(1) p-value	0.021**	0.014**	0.028**	0.019**	0.041**	0.054**	0.064*	0.023**	0.071*
AR(2) p-value	0.745	0.125	0.541	0.458	0.742	0.635	0.565	0.145	0.452

Note: the use of the fixed effects specification is justified after a Hausman test for each model. Standard errors in parentheses are robust to heteroschedasticity and to within group serial correlation. AR(1) and AR(2) are tests for serial autocorrelation. The numbers in square brackets are the *p*-values.

*** Significant at 1%, respectively.
** Significant at 5% respectively.
* Significant at 10% respectively.

Table 3
Dynamic panel SYS-GMM results.

Variables	(1) GEN	(2) CAP	(3) LAB
lnGEN (-1)	0.908*** (0.113)	–	–
lnGEN (-2)	−0.048 (0.090)	–	–
lnCAP (-1)	–	1.076*** (0.103)	–
lnCAP (-2)		−0.146 (0.164)	–
lnCAP (-3)		0.106 (0.123)	–
lnLAB (-1)	–	–	0.738 (0.037)
ln(GDP)	0.00004** (0.000)	0.0001*** (0.000)	0.017*** (0.003)
PRIV	0.049 (0.115)	−0.076* (0.048)	2.041 (13.079)
RRI	−0.047* (0.029)	−0.019*** (0.007)	−4.874** (2.121)
TPA	0.009 (0.056)	0.016 (0.014)	15.190* (8.220)
WHOL	0.123* (0.066)	0.038* (0.022)	0.339 (6.091)
EXPORT	−0.0001*** (0.000)	0.000003 (0.000)	−0.014*** (0.003)
FRASER	0.0001*** (0.000)	0.00003 (0.000)	0.253*** (0.017)
IND	0.000004 (0.000)	0.00001 (0.000)	0.045*** (0.003)
URBAN	0.0008 (0.007)	0.005 (0.004)	1.268** (0.590)
TREND	0.0003 (0.000)	0.0005*** (0.000)	0.047 (0.035)
Constant	3.647* (2.094)	0.355*** (0.132)	63.144 (45.259)
Diagnostics			
Observations	1050	844	1080
Number of countries	30	30	30
Number of instruments	80	96	148
AR(1) p-value	0.039*	0.006***	0.012**
AR(2) p-value	0.763	0.388	0.847
Sargan-Hansen test	25.259 [0.99]	17.709 [1.00]	26.092 [0.98]

Note: the use of the fixed effects specification is justified after a Hausman test for each model. Windmeijer corrected (robust) standard errors are in parentheses. AR (1) and AR(2) are tests for serial autocorrelation. The numbers in square brackets are the *p*-values.

*** Significant at 1% respectively.
** Significant at 5% respectively.
* Significant at 10% respectively.

that competition will lead to higher electricity generation per employee (Zhang et al., 2008).

The magnitude of the relevant coefficient when significant varies between 0.003 and 0.171. It is interesting to highlight that competition has the largest coefficient of any of the structural reform variables (PRIV and RRI). This result strengthens what has been found in other empirical studies (see for example Zhang et al., 2008), namely that effective competition is a key element of the electricity performance. Surprisingly, the impact of competition on the installed electricity capacity is absent since the relevant coefficients in all of the specifications are not statistically significant (see models 4–6).

It is worth emphasising that interaction terms between regulation and competition are not statistically significant and in some cases the relevant coefficient has a negative sign. These results indicate that it is competition on its own rather than competition and the establishment of an effective regulatory framework that is critical in explaining increased electricity performance. The interaction terms between privatisation and regulation are less easy to interpret. More specifically, the relevant coefficient is positive but not statistically significant in the models 2–3, which encounter the net electricity generation as the dependent variable. In contrast, the joint effect of regulation and privatisation is negative and statistically significant in the capacity model (see columns 5–6), while the outcome is opposite concerning the labour productivity model (see columns 8–9).

As expected, GDP per capita is strongly and positively correlated with all of the three indicators of electricity performance (GEN, CAP and LAB). The relevant elasticities range from 0.060 (model 4) to 0.677 (model 9), implying that a 10% increase in the per capita GDP will increase the level of installed electricity capacity and labour productivity by 0.6–6.7%. As expected, the level of industrialisation (IND) and urbanisation (URBAN) is positively correlated with electricity performance in nearly all of the estimated models. Surprisingly, the degree of openness of the economy, as reflected in the exports variable (EXPORT) has a negative and statistically significant impact on the electricity output (GEN and CAP). However, the relevant coefficient turns to be positive and statistically significant when assessing the labour productivity models (see columns 7–9). This indicates that the higher the level of economy's involvement in international transactions and trading rules, the more efficient is its electricity sector as expressed by the increase in the labour productivity. Surprisingly, the economic risk variable (FRASER) is negative and not statistically significant in all but one (see model 6) specification. Also as expected, the coefficient of the time trend (TREND) is in most models positive and statistically significant at 1% level, highlighting that electricity performance is growing over time.

As mentioned in the previous section, one of the main reasons of estimating a dynamic model is to capture short-run and long-run effects of the structural reform variables on the overall electricity performance measured by the three indicators (GEN, CAP, LAB). The long run effect in this case is calculated as $1/(1-\gamma)$ times the value of the coefficient of every independent variable. The Greek letter γ refers to the estimated coefficient of the lagged dependent variable (or the sum of all the lagged operators) in each of the nine specifications. In the case of privatisation the long run effect is derived by multiplying the above expression by either the estimated coefficient of PRIV (i.e short run effect), or the sum of the interacted coefficients (cross terms). As it is evident from Table 2, the short run effect of the privatisation variable when significant is negative (see columns 3, 4, 7, 8, 9). However, this finding is totally reversed when we account for the long-run effects of the privatisation variable on the level of output (GEN). This effect is positive and is almost two times greater in its (absolute) magnitude than the short run effect (0.779 compared to 0.472), revealing that privatisation causes some transient disruption to the level of output only in the short-run, whilst the opposite holds in the long run. The same finding can be identified in the interacted Models (8) and (9), where the transfer of public ownership towards privatised regimes creates a positive effect at least in the long-run. On the contrary, privatisation on its own does not alter the magnitude of labour efficiency in the long-run (see Model 7) since the sign of the relevant multiplier remains negative (-0.018).[8] It is worth mentioning that the above findings do not change when we include lagged levels of the privatisation variable on these models.[9]

Finally, the Sargan–Hansen test from the two-step homoscedastic estimate can not reject the null hypothesis in all of the specifications. This means, that the over-identifying restrictions are valid and satisfy the orthogonality conditions (Arellano, 2003; Roodman, 2009). In addition, according to the *p*-values of the Arellano–Bond test for autocorrelation it is evident that first-order autocorrelation in differences is allowed (AR1) since the idiosyncratic errors are serially correlated, whereas second-order autocorrelation is not (AR2). In this case, the error terms are independent over time allowing for the estimates to be consistent.

4.3. Robustness check

In order to check for the robustness of the dynamic GMM

[8] In the case of capacity utilization (see Model 4), the long run effect of the privatisation is nearly estimated to zero.

[9] The results are available on request.

analysis, we employ the system GMM (SYS-GMM) estimator that was designed to overcome some of the limitations of the DIF-GMM. The primary reason for using the SYS-GMM estimator is that the latter increases efficiency in cases where the lagged levels of the regressor are poor instruments for the first-differenced regressors. This may be true in our case because some of our instruments may be weakened as a result of the regulatory events. Moreover, Blundell and Bond (2000) showed that when the dependent variables are persistent (i.e. when the coefficients of the first lag of GEN, CAP and LAB are close to one), then the accuracy of the estimates is dramatically improved by the use of the SYS-GMM (Klumpes et al., 2015). Besides, the SYS-GMM estimator allows the examination of the impact of regulation competition and privatisation on electricity performance in more detail and is included in this paper in order to perform a sensitivity analysis.

Table 3 reports the results of the applied methodology.[10] Specifically, in terms of the structural reform variables, regulation and competition have the same effect as the previous dynamic model (DIF-GMM). However, the impact of the privatisation on performance is rather ambiguous since the relevant coefficients in the three specifications have provided mixed results. Regarding the labour efficiency, privatisation has no identifiable impact since the relevant coefficient although positive (2.041) is not statistically significant. The lack of a significant finding may reflect the opposing impacts on this measure discussed above, since privatisation induce firms to increase efficiency by reducing employment, but may also induce firms to increase employment to improve service (Wallsten, 2001). However, the magnitude of this coefficient when significant (CAP) is negative and equal to -0.076. When it comes to the country level macroeconomic variables, it is stated that they have the anticipated signs and are statistically significant.

5. Conclusions and policy implications

This study has focused on the determinants of electricity performance using a large data set of OECD countries over the period 1975–2011 and robust panel data econometric techniques (static and dynamic models). Structural variables, in particular regulation and competition variables, were found to explain differences in electricity performance levels between the OECD countries. At the same time certain macroeconomic variables such as GDP and the level of economic risk, also explain significant variation in the electricity performance.

However, privatisation in the electricity sector is negatively associated with its performance activity since in all of the specifications (static and dynamic ones) the relevant coefficients regarding the labour productivity and installed capacity come with the negative sign and in some cases are statistically insignificant. This means that the transfer of the ownership of the vertically integrated state-owned utilities into a more competitive and privatised scheme decreases or leaves unaffected the electricity performance at least in the short-run. This finding which is in alignment with similar empirical studies raises significant doubts on the effectiveness of the privatisation policies pursued in many of the OECD countries. Electricity industry is characterised by large sunk investments and significant externalities which are present in the distribution and transportation segments of the market (Newbery, 2000). These features of the industry may provide governments with the possibility of behaving opportunistically and thus private investors may be cautious about investing in capacity. Further the experience gained by the privatisation process in many developed countries (especially in the UK and in some US states) has showed that market prices have often lead to under-investment and an energy mix which does not guarantee security of supply, de-carbonization, and price affordability.

The message for policy makers is that effective regulation by the national authorities to foster competition in the electricity sector helps to achieve one of the policy goals set out in the Electricity Directives that is the encouraging of the investment. This can be implemented by pursuing policies targeting at the removal of entry barriers in the electricity sector and lifting the restrictions that impede competition in all of its segments. The paper is timely as several OECD countries (Greece, Portugal, Iceland, Korea, Mexico) are still at the initial restructuring stages since they have opened their electricity markets to meet minimum requirements of the electricity sector, while other member states (UK, Germany, Norway, Finland and Sweden) have acted as pioneers in the liberalisation process and pursued strategies focusing at full market opening and the introduction of effective competition in the generation and supply segments. Regulation of the electricity industry is relatively new and this study shows that it enhances the performance of the sector. Further improvement of market functioning, however, will require the use of both competition and regulatory powers. This requires close co-operation between the regulators and the competition authorities.

Concluding, the two dynamic methodologies confirm that effective competition and regulation are considerably more important in facilitating electricity performance than privatisation. It is noteworthy, that the effects of regulation are even more important than suggested by the static model since the majority of the relevant coefficients are statistically significant and larger in their magnitude. This outcome draws some important policy implications to the policy makers and the government officials. More specifically, in order to achieve a competitive electricity market, and allow for welfare maximization, a robust independent regulatory scheme must be implemented. In other words, regulation of the monopoly segments of the electricity industry (transmission and distribution) plays a crucial role in the promotion of effective competition which in turns leads to the increase of the electricity performance. This is explained by the fact that many OECD countries have firstly created a strong regulatory regime in order to introduce competitive pressures in the vertically integrated electricity industries and lower the significant market power of the incumbent companies.

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Appendix A

See Tables A1–A4 here.

[10] The interaction terms are omitted from the models since the relevant coefficients were not statistically significant. In order to choose the appropriate number of lags for our models, we followed a three step procedure. Firstly, we estimate all the relevant equations by allowing different lags of the dependent variables. In the next step we compare our results choosing the lag length that minimizes the Akaike Information Criterion (AIC), confirmed by Arellano–Bond (AR) tests and lastly, we argue that for the selected lag lengths, the residuals of our models are not correlated.

Table A1
Definition and variable sources.

Variable	Definition	Explanation/Data sources
Dependent variables		
GEN	Net electricity generation per capita	This variable refers to the net production of electricity per capita measured in Kilowatt hours. Data source: World Bank Development Indicators.
CAP	Installed electricity capacity per capita	This variable refers to the installed capacity per capita measured in million Kilowatts. Data source: U.S. Energy Information Administration (EIA)
LAB	Labour productivity per person employed.	This variable denotes the labour productivity in the electricity sector per person employed measured in constant (2011) US dollars. Data source: International Labour Organization.
Structural reform variables		
RRI	Regulatory reform index	This indicator represents the level of regulation in the OECD electricity sector taking the value from 0 to 6. A high (low) score in the RRI is attributed to countries characterised by a more (de) regulated sector (Conway and Nicoletti, 2006). Data source: OECD, International Regulation Database.
WHOL	Wholesale reform variable	This indicator measures the existence of a liberalised wholesale market for electricity (wholesale pool). It takes the value of one if a wholesale pool is existing, whilst is set to zero. Data source: OECD, International Regulation Database, World Bank Electricity Regulation Database and Latin American Energy Organization (OLADE).
TPA	Third-party access reform variable	This indicator accounts for the third party access to the electricity transmission grid within the sample countries. It takes the value of zero if TPA is absent otherwise is set to one. Data source: OECD, International Regulation Database, World Bank Electricity Regulation Database and Latin American Energy Organization (OLADE).
PRIV	Privatisation reform variable	This indicator refers to the ownership structure of the largest companies in all of the electricity market segments (i.e generation, transmission, distribution, and supply). If the ownership structure is (mostly) public then the dummy variable takes the value of zero otherwise is set to one. Data source: OECD, International Regulation Database.
Macroeconomic and other control variables		
GDP	Gross domestic product per capita	This variable refers to the gross domestic product per capita depicted in constant (2005) US dollars. Data source: World Bank Development Indicators.
EXPORT	Exports of goods and services / GDP	This variable stands for the openness of the economy and is estimated as the ratio of total exports to GDP Data source: World Bank Development Indicators.
FRASER	Level of economic freedom	This indicator denotes the 'economic risk' variable proxied by the FRASER index of economic freedom. The FRASER index consists of five factors: i) size of government, ii) legal system and property rights, iii) access to sound money; iv) freedom to trade internationally and v) regulation of credit, labour, and business. These are weighted to form a composite index, with 0 indicating the lowest and 10 the highest level of economic freedom (Gwartney et al., 2012). Data source: The Fraser Institute.
IND	Level of industrialisation	This variable is the percentage of industrial output as a share of GDP. Data source: World Bank Development Indicators.
URBAN	Level of urbanisation	This variable denotes the share of the population living in urban areas to total population. Data source: World Bank Development Indicators.
T	Linear time trend	This variable captures the effect of the technology on the electricity performance. Data source: Author's elaboration.

Table A2
Summary statistics and correlation matrix. *Source*: Author's elaboration.

	CAP	GEN	LAB	GDP	PRIV	RRI	TPA	WHOL	EXPORT	FRASER	IND	URBAN
Descriptive statistics												
Cross sections	30	30	30	30	30	30	30	30	30	30	30	30
Mean	3.20	25.26	10.99	10.05	0.17	4.16	0.59	0.73	38.42	7.20	30.81	74.66
Median	3.11	25.26	11.09	10.22	0.00	4.83	1.00	1.00	32.38	7.40	30.45	75.66
Maximum	6.95	29.10	11.75	11.38	1.00	6.00	1.00	1.00	181.78	8.84	47.27	97.46
Minimum	−0.36	19.70	9.70	8.22	0.00	0.00	0.00	0.00	5.16	3.55	13.19	42.79
Standard deviation	1.42	1.62	0.38	0.66	0.37	1.81	0.49	0.45	24.82	0.91	5.44	10.80
Coefficient of variation	0.44	0.06	0.03	0.07	2.25	0.44	0.84	0.61	0.65	0.13	0.18	0.14
Skewness	0.03	−0.57	−0.93	−0.85	1.80	−0.62	−0.36	−1.02	2.20	−0.90	0.10	−0.34
Kurtosis	3.34	4.60	3.58	2.98	4.24	2.00	1.13	2.05	10.09	3.63	3.32	3.01
Observations	834	834	834	834	834	834	834	834	834	834	834	834
Correlations												
CAP	1.00											
GEN	0.97**	1.00										
LAB	0.13***	0.08**	1.00									
GDP	0.02***	−0.02**	0.93***	1.00								
PRIV	0.49**	0.47***	0.26***	0.20**	1.00							
RRI	−0.28***	−0.30*	−0.43***	−0.33**	−0.42**	1.00						
TPA	−0.20**	−0.22	−0.39*	−0.29***	−0.20**	0.86**	1.00					
WHOL	−0.21***	−0.21***	−0.35***	−0.29***	−0.19***	0.82**	0.72***	1.00				
EXPORT	−0.59***	−0.64**	0.33**	0.30***	−0.15***	−0.11**	−0. 17***	−0.06***	1.00			
FRASER	0.19**	0.17**	0.76**	0.74**	0.28***	−0.47**	−0.42***	−0.35**	0.20***	1.00		
IND	−0.01**	0.04***	−0.46**	−0.42*	−0.20***	0.33**	0.34*	0.32**	−0.20*	−0.46**	1.00	
URBAN	0.06***	0.06***	0.53***	0.53***	0.31*	−0.23*	−0.17***	−0.19**	0.10***	0.43**	−0.30*	1.00

Note: GEN is the net generating electricity per capita, CAP is the installed electricity capacity, LAB stands for the labour productivity in the electricity sector. GDP stands for the per capita GDP in the sample countries, PRIV stands for the ownership structure of the largest companies in all of the electricity market segments, RRI stands for the OECD regulatory reform index in the industry, TPA accounts for the third party access to the electricity transmission grid, WHOL stands for the existence of a liberalised wholesale market for electricity (wholesale pool), EXPORT measures the exports as a percentage of GDP, FRASER stands for Fraser Index of Economic Freedom, IND, measures the industrialising rate, and URBAN stands for the urbanisation rate.

*** Significant at 1% respectively.
** Significant at 5% respectively.
* Significant at 10% respectively.

Table A3
Panel unit root test results.

Variable	Harris-Tzavalis	Levin, Lin and Chu-t test	Breitung test	Im, Pesaran and Shin W-test	ADF–Fisher Chi-square	PP–Fisher Chi-square	Hadri z-statistic
Levels							
CAP^{++}	0.874	−0.943	5.201	0.895	73.970	66.534	11.580^{***}
GEN^{++}	0.963	−0.012	2.674	2.264	51.462	52.559	14.123^{***}
LAB^{++}	0.839^{***}	−0.611	2.854	1.188	64.060	44.240	13.589^{***}
GDP^{++}	0.773	1.372	4.208	1.235	54.609	25.669	11.344^{***}
$PRIV^{+}$	0.948	0.243	n/a	1.206	1.624	1.621	6.975^{***}
RRI^{++}	0.999	−1.220	0.471	2.034	25.457	19.552	11.617^{***}
TPA^{++}	0.954	1.149	−3.944	1.311	27.875	28.623	10.646^{***}
$WHOL^{+}$	0.957	1.541	n/a	3.620	7.004	7.002	14.122^{***}
$EXPORT^{+}$	0.780^{***}	1.160	n/a	3.621	33.884	28.865	17.477^{***}
$FRASER^{++}$	0.924	−0.044	2.736	1.706	53.501	55.861	13.178^{***}
IND^{++}	0.754^{***}	1.863	4.476	1.742	42.159	41.529	12.187^{***}
$URBAN^{+}$	0.978	−13.561	n/a	0.067	72.046	249.627^{***}	18.772^{***}
First Differences							
Δ(CAP)	5.458^{***}	-16.219^{***}	-7.432^{***}	-16.468^{***}	342.275^{***}	495.332^{***}	7.099^{***}
Δ(GEN)	1.258^{***}	-22.297^{***}	-10.487^{***}	-24.260^{***}	574.392^{***}	1621.830^{***}	−0.186
Δ(LAB)	–	-18.689^{***}	-7.257^{***}	-18.591^{***}	415.388^{***}	517.569^{***}	4.227^{***}
Δ(GDP)	0.985^{***}	-15.184^{***}	-8.808^{***}	-14.298^{***}	305.998^{***}	326.055^{***}	3.379^{***}
Δ(PRIV)	3.659^{***}	-9.941^{***}	-9.413^{***}	-7.765^{***}	52.875^{***}	52.870^{***}	0.664
Δ(RRI)	2.458^{***}	-18.175^{***}	-17.455^{***}	-16.679^{***}	337.603^{***}	354.257^{***}	4.233^{***}
Δ(TPA)	1.485^{***}	-29.934^{***}	-27.985^{***}	-23.437^{***}	488.954^{***}	488.932^{***}	1.342^{*}
Δ(WHOL)	8.756^{***}	-23.780^{***}	-22.092^{***}	-18.633^{***}	307.211^{***}	307.193^{***}	1.039
Δ(EXPORT)	–	-24.383^{***}	n/a	-22.070^{***}	515.752^{***}	607.311^{***}	3.031^{***}
Δ(FRASER)	1.254^{***}	-29.039^{***}	-15.774^{***}	-26.727^{***}	614.764^{***}	2100.380^{***}	4.823^{***}
Δ(IND)	–	-13.572^{***}	2.039^{***}	-15.332^{***}	327.716^{***}	453.284^{***}	6.060^{***}
Δ(URBAN)	3.659^{***}	-2.925^{***}	n/a	−0.971	63.696	–	11.433^{***}

Note: GEN stands for the net generating electricity per capita, CAP stands for the installed electricity capacity, LAB stands for the labour productivity in the electricity sector. GDP stands for the per capita GDP in the sample countries, PRIV stands for the ownership structure of the largest companies in all of the electricity market segments, RRI stands for the OECD regulatory reform index in the industry, TPA accounts for the third party access to the electricity transmission grid, WHOL stands for the existence of a liberalised wholesale market for electricity (wholesale pool), EXPORT measures the exports as a percentage of GDP, FRASER stands for Fraser Index of Economic Freedom, IND, measures the industrialising rate, and URBAN stands for the urbanisation rate. Under the null hypothesis Hadri test assumes the absence of a unit root whereas the other unit root tests assume a unit root. The lag lengths were selected by using Schwarz criterion. $^{+}$denotes the inclusion of an individual intercept as an exogenous regressor, $^{++}$ denotes the inclusion of an individual intercept and trend as exogenous regressors.

**Significant at 5% respectively.

*** Significant at 1% respectively.

* Significant at 10% respectively.

Table A4
Panel cointegration tests.

Dependent variable	*Fisher (combined Johansen)*	*Kao (Engle-Granger based)*
GEN	*Trace statistic* 2.77 $[r=0]$ 526.80^{***} $[r>=1]$ *Maximum eigenvalues* 2.77 $[r=0]$ 88.74^{***} $[r>=1]$	-4.084^{*}
CAP	*Trace statistic* 2.77 $[r=0]$ $264.80^{***}$$[r>=1]$ *Maximum eigenvalues* 2.77 $[r=0]$ $19.81^{***}$$[r>=1]$	-1.580^{**}
LAB	*Trace statistic* 1.39$[r=0]$ 61.28^{***} $[r>=1]$ *Maximum eigenvalues* 1.39 $[r=0]$ 93.30^{***} $[r>=1]$	-4.617^{***}

Note: GEN is the net generating electricity per capita, CAP is the installed electricity capacity, LAB stands for the labour productivity in the electricity sector. Null hypothesis implies absence of cointegration, while r denotes the number of cointegrating equations with linear deterministic trend.

*** Significant at 1% respectively.

** Significant at 5% respectively.

* Significant at 10% respectively.

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