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Industrial electricity prices in the European Union following restructuring: a comparative panel-data analysis

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Abstract

This paper analyses the impact of regulatory reform on industrial electricity prices, and the differential between industrial to household prices, for the period 2003 to 2013 in 15 European Union countries. A static econometric panel-data model is applied, supplemented by a dynamic model, which includes the possible effect of endogeneity. Our main conclusion is that electricity market reform has not resulted in a reduction in prices for industrial users. Moreover, the findings suggest that industrial consumers have largely borne the costs derived from the reform process. Among the variables considered, only third-party access appears to be related to lower industrial prices and a lower price differential.

Keyword

Electricity prices; Electricity market reform; European Union; Panel data model.

1. Introduction

Electricity is currently a prominent source of concern for economic, social, and political agents. The increased deterioration of the environment, including the problem of climate change, problems of security of supply in the European Union (EU), the depletion of fossil fuels, and continued aversion to the use of nuclear energy are all factors that have led to both increases in energy efficiency and the use of renewable and less polluting energy sources. However, setting up a competitive electricity sector in the EU is also a fundamental objective for all of the countries concerned.

Traditionally, the four activities of the electricity industry (generation, transmission (high voltage network), distribution (low voltage network), and retail service to end consumers) were vertically integrated. The industry worked as a regulated monopoly, and it is very common for there to be a small number of providers (government-owned or municipal) in a highly regulated market. In these regulated markets, users have limited opportunities to switch to alternative suppliers. However, the early 1980s saw a process of restructuring the electricity sector across the world (Patterson 1999, Erdogdu 2013).

In general, electricity industry reform has had the following four dimensions:

i) unbundling (separation) of energy production and supply activities from the operation of transmission networks;
ii) opening entry to new competitors, including Independent Power Producers (IPP);
iii) allowing for third-party access and retail services; and
iv) privatising publicly owned assets.

European legislation remains neutral as regards this last dimension (for a more in-depth revision of the reasons and the economic theory underlying the electricity industry market-based reform and the privatisation reforms see Nepal and Jamasb (2015), Patterson (1999), Jamasb and Pollitt (2001), and Fiorio and Florio (2013)).

Electricity reform trends have been very diverse in the different EU Member States, with the United Kingdom as the first to implement comprehensive electricity reform at the end of the 1980s and France as a latecomer in implementing EU directives (Fiorio, Florio 2007). In order to set up an Internal Energy Market (IEM), three packages of regulatory measures were adopted. These packages addressed improvements in market access and interconnection, better consumer protection, increased transparency, and supply adequacy. The first legislative package, passed in 1996, set rules for unbundling focusing on wholesale electricity markets. The second, in 2003, introduced a more specific set of regulatory rules related to tariff setting and the enforcement of network unbundling by Independent Energy Regulators (IER). The full opening of markets was envisaged by June 2007, extending the electricity reform to retail markets (Erdogdu 2013, Martínez de Alegría et al. 2009, Larsen et al. 2006, Streimikiene et al. 2013, ACER/CEER 2012, ACER/CEER 2015, Glachant, Ruester 2014). However, substantial inefficiencies relating to electricity markets were again detected. The main causes of the low level of competition in these markets were the high concentration of markets underpinned by insufficiently unbundled transmission system operators (TSOs) (European Commission 2006, ACER/CEER 2012). The third package of EU legislative acts on electricity sector reforms was adopted in 2009. The objective was to tackle the structural deficiencies in European electricity markets. Better cross-border coordination and greater independence for Independent Energy

Regulators (IER) and transmission system operators (TSOs) were required (ACER/CEER 2012, European Commission 2014, Streimikiene et al. 2013).

The objective of this paper is to examine the impact of a number of factors closely linked to the regulatory reforms carried out in the EU on electricity prices for industrial consumers and on the ratio of industrial prices to household prices. As pointed out by Nagayama (2007), the Pi/Ph ratio is an indicator of enhanced competition. This author also asserts that, as the electricity sector reforms progressed, the cross-subsidy from industrial to residential users tends to be reduced and both electricity prices become cost reflective so that a lower industrial price relative to residential price is realized. We follow the earlier research line started by Steiner (2000) and subsequently continued by Hattori and Tsutsui (2004) and by Nagayama (2007). Recently, Hyland (2016) looked at the restructuring of European electricity market, taking into account the possible endogeneity of the reform process. The purpose of the present study is specifically to contribute to a better understanding of the effects of the reforms that started in the 1990s in the 15 European Union countries (the EU-15), focusing on the 2003 to 2013 period, which includes the period between the 2nd and 3rd EU "electricity sector reform packages". The empirical econometric analysis is based on a panel data model for the period, including dynamic panel data techniques as proposed by Hyland (2016).

The rest of the article is organised as follows: Section 2 offers a review of the literature. Section 3 covers the data, including the explanation of the variables selected (Subsection 3.1) and descriptive statistics (Subsection 3.2). The econometric model and the methodology are addressed in Section 4. Results are delivered in Section 5. Subsection 5.1 focuses on the analysis of the static panel model, while Subsection 5.2

104 focuses on that of the dynamic panel model. Finally, Section 6 presents the conclusions
105 and policy implications of the study.

106 2. Review of literature

107 The effect of regulatory variables on electricity prices can be analysed from different
108 perspectives and econometric strategies. Likewise, the effect of electricity reform is
109 difficult to assess because it includes different interrelated steps, can occur in different
110 forms and models and is a dynamic process (Pollitt 2009a, Pollitt 2009b). As
111 explained by Nepal and Jamasb (2015), studying such reforms means tackling
112 institutional and organisational issues, such as the degree of intervention, competition,
113 and unbundling of vertically integrated organisations. Hence, market-based reform
114 measures are multi-dimensional activities with many interacting factors and a wide
115 variety of impacts that Social Cost Benefit Analysis (SCBA), econometric, and macro
116 and micro-analyses based on efficiency and productivity may not adequately capture.

117 Some analyses of regulatory reforms are from the consumer's point of view. For
118 instance, Bellantuono and Boffa (2007) analysed 10 EU Member States according to
119 the quality of their residential customer protection measures, focusing on demand-side
120 variables. Using a regression model they test the impact of retail market liberalisation
121 on consumer prices in the electricity and gas markets, focusing on the possibility of
122 customers choosing their supplier. They concluded that household prices are lower in
123 Member States where the retail markets have been liberalised. Florio (2007) studied
124 price signals and trends for the evaluation of reforms leading to market structure or
125 ownership changes, focusing on the evolution of electricity prices in Italy, Germany,
126 France, and the United Kingdom. He questions the validity of the "ideal pattern" of
127 *privatisation* and *vertical disintegration*. Borenstein and Bushnell (2015), offer a

review of restructuring in the electricity industry over the last two decades in the US, concluding that, the "electricity rate changes since restructuring have been driven more by exogenous factors – such as generation technology advances and natural gas price fluctuations- than by the effects of restructuring".

Table 1 shows our summary of the multi-country studies of the impact of regulatory reforms on price in the power industry using panel data models. The study published by Steiner (2000) based on panel data from 19 OECD countries is considered to be the first significant attempt to assess this impact. It concluded that ownership is not necessarily correlated with increased competition and that reforms do not generally mean a reduction in market power; in particular, the introduction of legal third-party access does not necessarily result in the actual entry of new retailers, as the effect of this variable is found to be not significant. In all countries and for the entire period analysed, industrial prices were found to be lower than household prices, suggesting that the benefits of reform are obtained disproportionately by industrial consumers and that price discrimination may increase under reform unless market power is reduced by structural measures (such as horizontal unbundling) (Steiner, 2000).

Hattory and Tsutsui (2004) re-examined the analysis by Steiner and their results are compared. While Steiner provides results only on random effects, Hattori and Tsutsui include both random and fixed effect estimation. They conclude that expanded TPA is likely to reduce industrial prices and increase the price differential between industrial and household customers; they also find that increases in private ownership may lead to a reduction in power prices, but may not alter the price ratio. They also find, contrary to expectations, that the introduction of a wholesale spot market may have resulted in an increase in power prices (Hattori and Tsutsui, 2004).

Using panel data from 25 developing countries for 1985 to 2001, Zhang et al. (2005) study the effect of the sequencing of privatisation, competition, and regulatory reforms in electricity generation. They concluded that "establishing an independent regulatory authority and introducing competition before privatization is correlated with higher electricity generation, higher generation capacity and, in the case of the sequence of competition before privatization, improved capital utilization" (Zhang, Parker, and Kirkpatrick, 2005).

Nagayama (2007) investigated panel data from 83 countries in Latin America, the former Soviet Union, and Eastern Europe from 1985 to 2002, focusing on the effect of different reform policy instruments on electricity prices in those countries. The study concluded that the introduction of a wholesale pool market and unbundling do not necessarily mean a reduction in power prices. Nevertheless, jointly with an independent energy regulator (IER), unbundling could mean a reduction in those prices. The introduction of Independent Power Producers (IPP) and privatisation is associated with lower electricity prices but only in some of the regions analysed (Nagayama, 2007). Nagayama (2009) suggests that high electricity prices were a driving force for the adopting of liberalisation measures in the countries analysed, but that the measures adopted did not necessarily lead to lower electricity prices (Nagayama, 2009).

Erdogdu (2011a) did not find a uniform pattern as regards the impact of reform on cross-subsidy levels and price-cost margins (the electricity price-cost margin in his study “includes items such as capital costs, transmission and distribution costs, accounting profit of the electricity utilities and so on”). Instead, power consumption, income level, and country-specific features may be relevant (Erdogdu, 2011a). Erdogdu (2011b) suggested that the application of liberal market models in electricity

177 industries slightly increased efficiency in the power sector; he also detected a positive
178 relationship between the reform process and the percentage share of transmission and
179 distribution network losses, and found that the introduction of a decentralised market
180 model with competition has a limited increasing effect on power industry performance
181 (Erdogdu, 2011b). Erdogdu (2013) later suggested that progress towards electricity
182 market reform is associated with lower policy support for research and development
183 activities, threatening sustainable improvements in the electricity sector (Erdogdu,
184 2013). Like Erdogdu (2011a), Erdogdu (2011b) found that some country-specific
185 features (such as income level) are more important determinants for the industry than
186 the reform process itself. These considerations are confirmed by Baek et al. (2014),
187 who analysed the performance of the power industry after "liberalisation" of markets
188 according to country-specific features and concludes that "liberalisation" increases
189 competitiveness, depending on the liberalisation process adopted and on the economic
190 environment (Baek et al., 2014). The paper by (Fiorio and Florio, 2013), which focused
191 on the evolution of residential electricity prices over nearly three decades in the EU15,
192 found no uniform pattern in the effect of electricity reform measures, concluding that
193 public ownership is associated with lower net-of-tax household electricity prices in
194 Western Europe. Similarly, based on the study of the effect of regulatory reforms on
195 the EU-27 countries over the period from 1990 to 2011, Bacchiocchi et al. (2015)
196 identified asymmetric effects of regulatory reforms within two country groups in the
197 EU27, suggesting that although the reforms reduced the price of energy in the EU15,
198 the combined effects of privatisation and liberalisation are associated with higher
199 prices in the New Member States (Bacchiocchi, Florio & Taveggia, 2015). Based on
200 the short-run cost function, in which capital stock is treated as a quasi-fixed factor
201 input, a recent study by Ajayi et al. (2017) focused on performance in terms of cost

202 efficiency for electricity generation in the power sector in OECD countries, accounting
203 for the impact of electricity market structures. This study also considers the need to
204 model latent country-specific heterogeneity in addition to time-varying inefficiency.

205 Based on panel-data models, Moreno et al. (2012) focused on the effects of renewable
206 energy sources on electricity prices using a sample of 27 EU countries for 1998 to
207 2009. Their results show that the introduction of renewables had a small final effect
208 on the increase in household electricity prices, that liberalisation reforms may not
209 necessarily lead to a less concentrated market structure, and that there is no evidence
210 that less concentrated electricity markets lead to lower household prices. The paper by
211 Polemis (2016) analysed the effects of the regulatory reform on the performance of the
212 electricity sector for 30 OECD countries from 1975 to 2011, outlining the need to
213 implement a robust, independent regulatory scheme in order to achieve a competitive
214 power market.

215 Several authors (Nagayama, 2009; Growitsch and Stronzik, 2014; Hyland, 2016) noted
216 as an additional concern the possibility of endogeneity between price trends and
217 market reform. As pointed out by Hyland (2016), "just as restructuring may affect
218 prices, the decision to restructure may be influenced by prices"; she proposes the use
219 of dynamic panel-data techniques to overcome the endogeneity problem.

220 **Table 1: Main findings of studies on the effects of regulatory reforms on**
221 **electricity prices using panel-data models**

Authors	Sample period and countries	Main conclusions
Steiner (2000)	19 OECD countries 1986 to 1996	Ownership not necessarily correlated with increased competition; reforms do not generally mean reduction in market power; benefits of reform reaped disproportionately by industrial consumers.
Hattori & Tsutsui (2004)	19 OECD countries 1987 to1999	Extended TPA may reduce the industrial price and increase price differential between industrial and household customers; unbundling and introduction of wholesale spot market may result in a power price increase.

Nagayama (2007)	83 countries from Latin America, the former Soviet Union and Eastern Europe. 1985 to 2002	Introduction of wholesale pool market and unbundling may not lead to power price reduction; but jointly with an IER, unbundling may mean a reduction in those prices.
Nagayama (2009)	78 countries (Asia, Latin America, the former Soviet Union, Eastern Europe) 1985 to 2003	High prices drive market liberalisation, but market liberalisation does not necessarily lead to a reduction in electricity prices.
Erdogdu (2011a)	63 developed and developing countries; 1982–2009	No uniform pattern has been found to explain the impact of the reform process on the cross-subsidy levels and price-cost margins; power consumption, income level, and country-specific features may be relevant determinants for the aforesaid variables.
Erdogdu (2011b)	92 developed and developing countries; 1982–2009	Country-specific features seem to be more determinant for industry efficiency than the liberalisation process itself; a more decentralized market model with competition in the electricity sector has a limited increasing effect on power industry performance.
Moreno, López, and García-Álvarez (2012)	27 EU countries; 1998–2009	Small effect of greater penetration of renewables on household price increase; liberalisation reforms may not lead to less concentrated markets; less concentrated markets may not lead to lower household prices.
Erdogdu (2013)	27 countries around the world 1974–2008	Progress towards electricity market reform is associated with lower policy support for R&D activities, threatening sustainable improvements in the electricity sector.
Fiorio & Florio (2013)	12 EU countries; 1975–2007	Public ownership is associated with lower net-of-tax household electricity prices in Western Europe.
Bacchiocchi, et al. (2015)	27 EU countries; 1990–2011	Regulatory reforms reduced the price of energy in the EU15; the combined effects of privatisation and liberalisation are associated with higher prices in the New Member States.
Polemis (2016)	OECD countries; 1975–2011	A robust independent regulatory scheme is necessary in order to achieve a competitive power market.
Hyland (2016)	27 EU countries plus Norway; 2001–2011	Proposes the use of dynamic panel-data techniques to overcome the endogeneity problem detected between price trends and market reform.

3. Data

Our dataset is based on a panel consisting of 15 European Member States from 2003 to 2013, so the potential maximum number of observations is 165. However, missing data mean that the effective number of observations is lower; the panel is thus unbalanced.

3.1. Variables

For dependent variables in the analysis, we use industrial price before tax (Pi) and the ratio of industrial price to household prices (Pi/Ph).

Industrial prices (Pi) correspond to the Ie band from 2003 to 2007 and the Ic band from 2008 to 2014) adjusted for US$ constant 2010 Purchasing Power Parities (PPP)[1]. Household prices (Ph) are prices before tax (for the dc band). All prices are obtained from Eurostat (2015). The US$ constant 2010 Purchasing Power Parities (PPP) are obtained from OECD (2015). There are some observations missing in the price data for the study period. Hattori and Tsutsui (2004) ensure that their results are robust by estimating the equation with and without these samples.

- For indicators not directly related to regulatory reform, we use the following variables:
  a) *Share of renewable energy in total electricity generation (in %)*, i.e., generated renewable electricity-ktoe (thousands of tons of oil equivalent))/ electricity generation of all sources-ktoe). Data are obtained from Eurostat (2015). The increase in the share of total energy production accounted for by renewable generation sources and increasing environmental concern justify the use of this indicator.
  b) *Gross* Domestic *Product per capita (GDPpc)*: data obtained from Eurostat (2015). As explained by Hyland (2016), the GDPpc is a variable commonly included in reduced-form models examining the determinants

[1] Data extracted on 29 Oct 2015 14:44 UTC (GMT) from OECD Stat; this dataset contains Purchasing Power Parities (PPPs) for all OECD countries. PPPs are the rates of currency conversion that eliminate the differences in price levels between countries (OECD=100)

of electricity prices, this variable may also capture information about the structure of the economy and the overall level of economic development.

- For reform indicators, we use the following variables as a proxy of the regulatory and policy impacts that they are meant to assess:
  a) *Public ownership*: this variable measures the percentage of shares owned directly or indirectly by the government in the largest firm in the sector (% of shares owned by the government/100*6) (OECD 2013).
  b) *Sector regulation (i.e., entry regulation)*: This variable measures the following 3 questions:
     - "Is there a liberalised wholesale market for electricity?" As explained by Hattori and Tsutsui (2004), this variable indicates whether there is a wholesale power pool market where hourly or half-hourly spot prices are determined. The variable takes a value of 6 if there is no such market and 0 when there is.
     - "How are the terms and conditions of third-party access (TPA) to the electricity transmission grid determined?" This takes a value of 0 if there is "regulated TPA", 3 if there is "negotiated TPA" and 6 if there is "no TPA". This variable is similar to the Retail Access or TPA used by Steiner and Hattori and Tsutsui.
     - If there is regulated TPA, "What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier?" This variable takes a value of 0 if there is "no minimum consumption threshold", 6 when there is "no consumer choice" and other values in between.

c) *Vertical integration* (i.e., compared to *unbundling*): this variable measures the degree of vertical integration between a certain segment of the electricity sector and other segments of the industry[2]. This is similar to the unbundling indicator in Steiner (2000) and Hattori and Tsutsui's (2004) studies.

The scores for these three indicators ("public ownership", "sector regulation" and "vertical integration") range between 0 and 6 (from least to most restrictive). All data are obtained from OECD (2013). The methodology for the OECD indicators of regulation in energy, transport, and communications (ETCR) is described in detail in (Koske et al. 2015).

d) *Retail access* or *third-party access (TPA)*: data source Eurostat (2015). To measure this effect we use the following two indicators or sub-variables:

- *The number of main electricity retailers*: retailers are considered as "main" if they sell at least 5% of the total electricity consumed nationwide. This 5% limit is set taking into account the criteria used by Eurostat (2015).
- *Total number of electricity retailers to end customers*

The purpose of using these two indicators is to assess the functioning of the retail markets when (industrial or household) consumers can directly reap the benefits of the introduction of competition if the entry of new

[2] Simple average over four segments: generation (including imported power), transmission, distribution, and retail services. The values of the variable are as follows: ownership separation =0; legal separation=3; accounting separation= 4.5; no separation=6

suppliers is facilitated and the engagement of consumers is promoted, enabling them to take full advantage of greater choice and better prices.

e) The following regulatory reform indicator is included as a potentially relevant variable for explaining changes in the dependent variables selected:

- *Regulated prices*: data obtained from ACER/CEER (2015). This is a dummy variable where 1 corresponds to yes and 0 to no. (We use this variable as corresponding to the "Time to liberalisation" and "Time to privatisation" indicators in Steiner and Hattori and Tsutsui's studies. The reason is that their periods of analysis end in 1996 and in 1999 respectively (i.e., running into the launching of the EU's 1st "electricity sector reform package") while ours extends to just after the 2nd package and includes four years after the 3rd. We thus consider the variable "existence of regulated prices" as more useful for measuring the level of liberalisation of the market, especially considering that, as pointed out by ACER, competition is compromised in countries where there are regulated end-user prices (ACER/CEER 2015).

As illustrated in Table 2, the average increase in industrial prices in the EU-15 from 2003 to 2014 was 67%. It must be stressed however that there are reductions in the average industrial price in 2013 and 2014 (of 1% respectively), which may be a positive sign, especially if this change of trend is maintained in the coming years. However, a longer period of observation is needed.

The average variation in industrial prices differs notably from one Member State to another. In the United Kingdom, Spain and Greece the Pi % increase is considerably

higher than the EU-15 average (161%, 142%, and 123% respectively). By contrast, the Netherlands (with a reduction of 2% between 2005 and 2014), Germany, Sweden, and Finland (with increases of 11%, 23%, and 26% respectively) show % Pi increases considerably below the EU-15 average.

Table 2: Annual trend in Industrial prices (%) (adjusted for PPP in constant 2005 US $)

GEO/TIME	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	% increase (2003-2014)
Austria	10	12	5	20	14	9	-6	-1	-1	-3	-6	62
Belgium	-2	-2	25	-3	6	8	-6	6	-2	-3	-2	24
Denmark	-7	2	18	-13	25	-7	14	-2	2	7	8	50
Finland	-4	-3	1	-1	15	10	0	2	2	2	-1	26
France	1	1	1	2	7	8	5	5	5	1	0	42
Germany	4	9	10	5	-2	5	-7	-4	-1	0	-6	11
Greece	0	4	1	5	25	1	3	23	15	4	5	123
Ireland	3	11	11	12	26	-10	-3	5	13	0	-7	71
Italy	1	7	17	6				6	8	-6	-3	56
Luxembourg	2	9	11	9	-1	23	-15	1	7	-5	-3	39
Netherlands	----	----	7	4	-2	8	-11	-5	3	-1	-4	-2
Portugal	3	7	13	6	-9	17	-5	5	20	-1	3	72
Spain*	3	29	8	-1	31	12	3	4	7	3	-2	142
Sweden	-2	-7	27	-3	17	-6	18	4	-6	-2	-11	23
UK	0	21	38	15	5	4	-6	3	17	1	10	161
EU-15	1	16	13	4	1	6	6	3	6	-1	-1	67

Some data are missing for the Netherlands for 2003 and 2004, so the % corresponds to the variation between 2005 and 2014.

In regard to effects on price differential (Pi/Ph), industrial prices are lower than household prices in all countries and at all times. However, this difference tends to increase in the Netherlands, Sweden, Belgium, Ireland, Germany and Denmark, where the Pi/Ph ratios have fallen by around 22%, 20%, 16%, 14%, 3% and 2% respectively (see Table 3). However, the gap decreases in the rest of the countries, which means that household consumers there paid comparatively more percentage-wise than

industrial consumers in 2014 than in 2013. The average EU-15 % increase is 11.6%, a figure that suggests that reforms have favoured household consumers more than industrial ones.

Table 3: Trend in the price ratio (industrial prices (Pi)/household prices (Ph))

Member state	% increase (2003-2014)
Austria	6.6415
Belgium	-16.6535
Denmark	-2.2591
Finland	-15.9872
France	11.5891
Germany	-2.8107
Greece	-11.2854
Ireland	-14.3540
Italy	25.0180
Luxembourg	15.1552
Netherlands*	-21.8205
Portugal	58.5687
Spain	7.0988
Sweden	-20.1540
United Kingdom	38.2853
EU-15	11.6480

There are data missing for the Netherlands for 2003 and 2004, so the % corresponds to the variation between 2005 and 2014.

4. Econometric Methodology

We formulate two independent regression equations to study the impact of restructuring, regulatory reforms, and other factors on industrial prices and the ratio of industrial to household prices following Steiner (2000) and Hattori and Tsutsui (2004). With the industrial price level being *Pi*, we first define the static panel-data model for country *i* at time *t* by:

$$Pi_{it} = c + h_i + R'_{it} b + X'_{it} g + \xi_{it} \qquad i = 1;...;I \text{ and } t = 1;...;T \qquad (1)$$

and denoting the price ratio (industrial price/household price) as *Pi/Ph*, the static panel model is written as:

$$(Pi\ /\ Ph)_{it} = c + h_i + R'_{it}b + X'_{it}g + \xi_{it} \quad i = 1;...;I \text{ and } t = 1;...;T \qquad (2)$$

R' is a set of regulatory reform indicators and *X'* is a set of independent variables not directly related to regulatory reforms; h_i indicates an unobservable time-invariant country-specific effect and ξ_{it} is the normal disturbance term. Following Hattori and Tsutsui (2004), we assume that there is a country-specific effect, so we estimate a static fixed effect model. Country fixed effects are included to control for any unobserved country-specific characteristics that do not vary over time. Since we can assume that the unobserved country-specific characteristics are uncorrelated with the variables included, a random effect model is also considered.

To avoid the possible problem of heteroscedasticity or autocorrelation, we compute robust standard deviations using the HAC estimator.

Possible endogeneity of the reform process is likely to be an important issue for consideration in the estimation. It is accepted that EU legislation has been an important driver of reform in some countries, but other countries have restructured and liberalised much faster than mandated by EU policy. This implies potential causality and thus the regressors may be correlated with the error term. Therefore, we also estimate a dynamic panel model where we include a lagged dependent variable to capture the persistence of the price variable (i.e., it considers the effect that trends in electricity prices may have on the independent variables selected):

$$Pi_{it} = c + h_i + R'_{it}b + X'_{it}g + pi_{it-1}a + \xi_{it} \quad i = 1;...;I \quad t = 2;...;T \qquad (3)$$

$$(Pi/Ph)_{it} = c + h_i + R'_{it}b + X'_{it}g + (Pi/Ph)_{it-1}a + \xi_{it}\ i = 1;...;I \quad t = 2;...;T \quad (4)$$

The error terms in equations 3 and 4 are simultaneously autocorrelated and correlated with the lagged dependent variable. This is due to the way in which the equations are constructed, so an estimator that takes both issues into account is needed. Greene (2012) and Wooldridge (2002) argue that in this context a fixed-effects approach is not appropriate since the correlation biases the coefficient of the lagged dependent variable and of any explanatory variable correlated with the lagged dependent variable. Nickell (1981) shows that this problem is very substantial, especially when the time frame of the panel is short. To overcome the problem, a GMM estimator (Arellano and Bond 1991) employing an instrumental variable estimator can be useful. The instruments for the lagged dependent variable are constructed using the second and subsequent Y lags. Lags from any endogenous regressors can also be used as instruments. One and two-step GMM estimators are computed.

5. Results

5.1. Results of the static panel-data analysis

We present the results of the regression analysis for industrial prices. The parameter estimates are shown in Table 4. Columns 1 and 2 present the results of the regression of the determinants of industrial electricity prices. The Hausman test indicates that the fixed effects model should be chosen, but we present the results of both models for the sake of comparison.

Table 4: Static Panel Model

Variable	Pi in constant 2010		Pi/Ph	
	Fixed effects Robust errors (HAC)	**Random effects**	**Fixed effects Robust errors (HAC)**	**Random effects**
Constant	1.0889*** (0.069)	1.1197*** (0.134)	5.1470*** (0.610)	5.1794*** (1.306)
Share of renewables in generation	0.3193*** (0.078)	0.3321*** (0.097)	5.3513*** (0.756)	5.4073*** (0.950)

Public ownership	-0.0705*** (0.023)	-0.0690** (0.029)	0.4214** (0.188)	0.4427* (0.281)
Sector regulation	-0.0538*** (0.008)	-0.0578*** (0.008)	-0.4721*** (0.078)	-0.4852*** (0.078)
Vertical integration	-0.0384*** (0.013)	-0.0429*** (0.013)	-0.0976 (0.105)	-0.1179 (0.128)
Number of major retailers	-0.0206* (0.011)	-0.0267** (0.011)	-0.3480*** (0.055)	-0.3680*** (0.103)
Number of retailers to end consumers	-0.0003*** (0.00007)	-0.0003*** (0.00008)	-0.0028*** (0.00045)	-0.0028*** (0.00079)
Regulated prices	0.2890*** (0.046)	0.3035*** (0.040)	2.4135*** (0.232)	2.5173*** (0.393)
GDPpc	0.0912*** (0.033)	0.0836*** (0.026)	0.4725*** (0.103)	0.4206* (0.256)
R^2	0.6245		0.5018	
Number of observations	150	150	149	149
Hausman Test		7.9042		3.2220

Robust standard errors are in parentheses.
***p <0:01, **p <0:05,*p <0:1

The main results for the static model (columns 1 and 3 in Table 4) are as follows:

Effects on industrial price (Pi) levels:

- The coefficient for *share of renewable energy in total electricity generation* is significantly positive in relation to the industrial price (Pi). This result is not unexpected because, with the exception of hydropower generation, these are new technologies installed in the EU-15 electricity markets, and may not yet have taken full advantage of the high potential of scale and knowledge economies. These results may be consistent with Moreno et al. (2012), who concluded that household prices tend to increase with the deployment of renewable energies. Moreover, it is also possible that industrial prices may have absorbed a larger part of the costs of introducing renewable energies than households.
- The coefficient for *GDPpc* is also significantly positive, as expected. This is consistent with Nagayama's (2009) result, which illustrates that such correlation is also positive in all areas except in Latin American countries.

- The coefficient *for share of public ownership* is significantly negative. This result is consistent with those of Zhang et al. (2005) and Steiner (2000). The underlying reason may be that in some EU countries these are highly concentrated or monopolistic markets (Steiner, 2000; ACER, 2015). By contrast, Hattori and Tsutsui (2004) suggest that private ownership may lead to a reduction in power prices. This difference between their results and ours could be mainly due to study timeframes.

- The coefficient *for vertical integration* is significantly negative. Our result suggests that unbundling or ownership separation does not necessarily have a positive effect on the reduction of industrial prices in the EU-15 electricity market. However, this does not fit with the results obtained by Kwoka and Pollit (2010), who focus on the performance impact of the merger wave which took place in the US electric power industry during the period 1994-2003 and find clear evidence that acquiring firms do not exhibit superior efficiency prior to merger, nor are acquired firms underperformers (Kwoka and Pollit, 2010). As in the case of *public ownership*, this could be due to the existence of highly concentrated markets coupled with possible obstacles for the third-party access (TPA), which may make it more difficult for new entrants to enter, and the consequent impossibility for these new entrants to offer lower electricity prices.

- R*etail access or third-party access (TPA).* This variable is measured as the *number of main electricity retailers* and the *number of electricity retailers to end customers*. As expected, the coefficients are significantly negative, so we conclude that the entry of new competitors may be effective in lowering

industrial prices. This result is consistent with those of Steiner (2000) and Hattory and Tsutsui (2004).

- Unexpectedly, the coefficient for *sector regulation* is significantly negative. This finding is in line with the results of Zhang et al. (2005), who concluded that privatisation and regulation do not alone lead to obvious gains in economic performance, though there are some positive interaction effects. We note that their study used different dependent variables and focused on developing and transitional economies.
- Unexpectedly, the coefficient for *regulated prices* variable is significantly positive. It may be (as in the case of the variable *share of renewable energies*) that some of the costs derived from the regulatory reform process have been borne especially by industrial consumers. However, this variable is not found in any of the other panel-data analyses considered, so we cannot make an effective comparison.

We clarify that we have obtained the variable for sector regulation according to the OECD (2013) methodology, which considers three sub-variables jointly. Our results suggest that when there is no *wholesale power market,* when there is no (or low) *third-party access (TPA)*, and when *the minimum consumption threshold* is higher (or *there is no consumer choice at all)*, the industrial price tends to be lower. As can be seen, this result is inconsistent with our result suggesting that TPA is associated with lower Pi. This incongruity may be due to several reasons. As explained, it might be because the TPA as obtained from the OECD is measured in conjunction with the other two variables mentioned above, which may lead to a distorted result. It might also be due to the different sources used (Eurostat, 2015 versus OECD, 2013). Thus, a definitive conclusion as to the effect of the sector

regulation variable cannot be obtained from the present analysis, and a more in-depth analysis is necessary to obtain more robust results, especially in terms of measuring the independent effects of the three sub-variables. We find that the result for the TPA variable obtained from Eurostat (2015) is more consistent with the expectation that improved access leads to reduced prices.

Effects on price differential (Pi/Ph):

- The coefficient for s*hare of renewable energy in total electricity generation* is significantly positive (as in the industrial price analysis), which may favour household consumers. In other words, the effect of an increase in renewables is more noticeable in explaining industrial price increases. A possible explanation is that industrial prices are more open to market forces than household prices so, as explained for the case of the effect on Pi, some of the costs derived from the regulation reform process may have been borne especially by industrial consumers.
- Unexpectedly, the coefficient for *GDPpc* is significantly positive, which suggets that an increase of the GDPpc is associated with a relative reduction of the household prices (comparing to industrial prices), a possible explanation could be due to the existence of subsidized prices in the household market.
- *The* coefficient *for public ownership share* is significantly positive. So, unexpectedly, public ownership is associated with a wider gap between Pi and Ph, which may favour household consumers over industry consumers. One possible explanation is yet again the lack of real competitive markets. These results are consistent with the significantly negative coefficient between public ownership and Pi, and are in line with the results of Steiner (2000). In Hattory

and Tsutsui (2004) private ownership has no significant effect on the Pi/Ph ratio.

- The coefficient *for sector regulation* (i.e., *entry regulation*) variable is significantly negative. This result seems to contradict the results for *public ownership share*. As in the analysis of the effects on industrial price (Pi) levels, we cannot draw a final conclusion from this result. As mentioned above, we believe that a more in-depth analysis of the *sector regulation* variable is needed.
- *The* coefficient *for regulated prices* is significantly positive, which favours households over industrial consumers. Once again, a possible explanation is that when there is *public ownership* there is a greater tendency to have subsidised prices for households.
- We did not find a statistically significant result for vertical integration.
- As expected, the coefficients fo*r* the *number of main electricity retailers* variable is significantly negative, as is that for *the total number of electricity retailers to end customers*. Again, TPA for retail services is expected to increase in the level of competition in power markets, in which industrial customers participate. These results are consistent with those for the Pi effect as regards the TPA variable.

We reiterate that the different time periods considered, differences in the definition of the explanatory variables, and the diversity of the multi-country groups considered must be taken into account when comparing our results to those of prior studies.

5.2. Results of the dynamic panel-data analysis

Hyland (2016) emphasizes that it is important to consider possible endogenous effects and suggests that doing so may alter the results of panel-data analyses in this area. She affirms that "any analysis that ignores dynamics and possible endogeneity is likely to miscalculate the effects of restructuring". Considering this, we also estimate a dynamic model containing lags of the dependent variable and the rest of the predetermined explanatory variables (see Table 5). As can be observed, the results of the dynamic panel model are quite similar to those obtained from the static model. The signs of the coefficients obtained are identical in both models. The notable differences are the level of significance of the variables, which is lower in the dynamic model, and the effect of the *number of major electricity retailers,* which is insignificant when the dynamic model is applied to the effect on industrial prices, as is the *GDPpc* when the model is applied to the Pi/Ph ratio.

Table 5: Dynamic Panel Model

Variables	**Pi in constant 2010**		**Pi/Ph**	
	One-step model	Two-step model	One-step model	Two-step model
Constant	0.0169* (0.010)	0.0264* (0.014)	0.1643** (0.072)	0.0982 (0.119)
Share of renewables in generation	0.2992* (0.175)	−0.1386*** (0.244)	7.8843*** (1.533)	7.204*** (2.186)
Public ownership	−0.0656* (0.036)	−0.1168*** (0.041)	0.7673*** (0.240)	0.8352*** (0.321)
Sector regulation	−0.0420*** (0.009)	−0.0330*** (0.004)	−0.4972*** (0.080)	−0.5009*** (0.101)
Vertical integration	−0.0366*** (0.014)	−0.0383*** (0.009)	0.1083 (0.089)	0.0381 (0.095)
Number of major retailers	−0.0168 (0.014)	−0.0343** (0.015)	−0.1460* (0.078)	−0.2558* (0.140)
Number of retailers to end consumers	−0.00011 (9.38e-05)	−1.747e-05 (7.50e-05)	−0.0014** (0.0006)	−0.0019*** (0.0006)
Regulated prices	0.3261*** (0.042)	0.2821*** (0.072)	2.5423*** (0.256)	2.418*** (0.300)
GDPpc	0.0665** (0.030)	0.0681* (0.039)	0.0451 (0.173)	0.0959 (0.231)
Pi (without taxes) lagged	−0.1889*** (0.058)	−0.1093 (0.075)		

Pi/ph (without taxes) lagged			−0.1747*** (0.064)	−0.1336* (0.077)
Sargan Test (Pr>χ^2)	108.905(p-value=0.00)	8.8915(p-value=1.000)	77.1095 (p-value=0.0212)	12.5927(p-value=1.000)
Arellano-Bond AR(1) test (Pr>z)	-1.9522 (p-value=0.0509)	-1.5290 (p-value=0.1263)	-3.0949 (p-value=0.0020)	-3.1166 (p-value=0.0018)
Arellano-Bond AR(2) test (Pr>z)	-4.0301 (p-value=0.0001	-2.7072 (p-value=0.0068)	-1.7404 (p-value=0.0818	-1.8414 (p-value=0.0656

Robust standard errors are in parentheses.
***p <0:01, **p <0:05,*p <0:16.

6. Conclusions and Policy Implications

In the last twenty years, electricity market and regulatory reforms have been proposed as a way of increasing competition and reducing prices. Generally, these policy reform packages have included unbundling, market entry, *third-party access*, and privatisation of publicly owned assets. The EU has remained neutral on this last issue. This paper measures the impact of a number of variables closely linked to the regulatory reforms carried out in the EU-15 on industrial electricity prices and the differential between industrial and household prices.

Contrary to expectations, we observe that industrial prices increased by an average of 67% from 2003 to 2014, with wide variations from one EU-15 country to another. However, between 2013 and 2014, this price fell markedly, which may be a positive sign if this trend is maintained in the coming years. This may be the result of the last energy reform package launched in 2009.

In regard to the static panel-data model, when focusing on the effects on the industrial price, we observe that an increase in *GDPpc* and the *share of renewable energies in total electricity generation* tends to be associated with higher industrial prices. When the regulatory reform variables are studied, the effect of the power market reform is not always as expected and not all the measures analysed are associated with a

reduction of industrial prices. Indeed, *unbundling*, *regulated prices*, and privatisation are not necessarily associated with lower prices, and they may indeed have effects contrary to expectations. Our results suggest that third-party access (measured as the *number of main electricity retailers* and the *total number of electricity retailers to end customers*) is related to lower industrial prices. A more in-depth analysis is needed to explain the unexpected result concerning the *vertical integration* variable.

With regard to effects on price differential, most of the variables analysed (*share of renewables, GDPpc; regulated prices; and public owners*hip) lead us to affirm that because industrial prices are more open to market forces than household prices (which in turn may be more subject to political decisions or subsidised prices), some of the costs derived from the regulatory reform process may have been borne especially by these industrial consumers. Consistent with the findings obtained for effects on Pi, TPA is the only factor associated with a lower price differential. One exception is the *sector regulation* variable, the effects of which need to be analysed in greater depth.

As illustrated, although industrial prices are lower than household prices in all countries and at all times, the change in the differential varies, with the average increase for the EU-15 being 11.6%. This figure suggests that on average reforms have favoured household over industrial consumers. The underlying reason may be that in some EU countries, electricity markets are highly concentrated (Steiner, 2000; ACER, 2015). These findings are understandable if industrial consumers are more exposed to market forces than households while government policies are aimed at other goals (such as reducing energy poverty or winning elections). However, we agree with Steiner (2000) that industrial consumers that use more energy can benefit more directly from *TPA* (e.g., by arranging to have power supplied by a generator, thereby avoiding other parts of the supply chain). Our results suggest that *TPA* leads to a reduction in

562 industrial prices. However, jointly considering most of the indicators analysed, our
563 results suggest that *unbundling* does not necessarily guarantee an improvement in *TPA*
564 and retail markets, especially when, as mentioned, monopolistic structures persist.

565 Comparing the static and dynamic panel models, we found that an increase in
566 renewables in the energy mix tends to increase industrial prices under the static panel
567 model; this result coincides with the findings of Moreno et al. (2012). The only notable
568 difference is the level of significance of the variables, which is lower in the dynamic
569 model. These results differ from those of Hyland (2016), who found that once the
570 potential endogeneity of reform is accounted for very few electricity reform variables
571 remain significant. However, we agree with her that accurate estimation of the long
572 term effects of reform will need further analysis over longer time periods, as the
573 restructuring and reform processes may not yet have had sufficient time to influence
574 electricity prices; and that further research is needed in regard to the use of dynamic
575 modelling.

576 Finally, as discussed there is no consensus among authors as to the effect of electricity
577 reforms in different country groups based on panel-data analysis. As shown in our
578 analysis, the effects of the reforms have been very diverse in European Union Member
579 States. With a view to drawing more robust conclusions and in line with the
580 observations of other authors (Erdogdu, 2011a, Bacchiocchi et al., 2015, etc.), a more
581 in-depth analysis by sub-groups of countries (e.g., The NordPool member countries
582 versus other sub-groups of countries with sub-groups identified according to their price
583 trends) is recommended, specially to better understands results around the Pi/Ph ratio
584 (as for example, in order to explain more adequately the positive coefficient for
585 GDPpc). A more thorough analysis is also recommended, in particular, to better

explain the causes of the unexpected results, especially those for the *sector regulation*, *unbundling* and the *regulated prices* variables.

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