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# Electricity prices and public ownership: Evidence from the EU15 over thirty years

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ABSTRACT

This paper studies 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. After a discussion of a simple conceptual model, and of earlier literature, we use IEA and OECD data for the EU15 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. The impact of liberalisation on prices is smaller and more uncertain.



## 1. Introduction

In the past two decades privatisation and liberalisation of network industries providing services of general economic interest, particularly in the energy sector, have been particularly significant in the European Union (EU).

In the 1990s the United Kingdom was the front-runner of electricity reforms, while, among the EU Member States, France has often been regarded as a country averse to moving away from public monopoly. In fact, in the last 20 years virtually all European countries have undertaken dramatic regulatory reforms of their electricity industries. Wide variations around a common policy trend can, however, be observed across countries, allowing us to assess the effects of the policy reform, and to study its effects on users.

A typical 'British-style' reform package has four main dimensions (see e.g. Helm, 2007; Newbery, 2000; Newbery and Pollitt, 1997; Pollitt, 2008; Rutledge, 2011): divestiture of public ownership; unbundling of the transmission network from generation and supply; price regulation by an independent office (usually in the form of price capping of certain services); and lifting of restrictions to market entry. According to some early views, price controls had to be considered as a transitory mechanism to protect the consumer before full liberalisation, so that only generic anti-trust vigilance was needed at the end of the process or only regulation of access to the network.

In general, the EU institutions have been strongly supportive of this reform approach, but more neutral on public ownership divestiture. Over the years the European Commission has proposed a number of important directives on the electricity sector, that push the Member States towards a homogenous pattern of regulatory legislation (see e.g. CEC, 2007). We want to test the "British-style" paradigm on empirical grounds, disentangling the effect of ownership from that of other regulatory dimensions and other shifts.

In this paper, we consider EU15 only, because data for the New Member States are less reliable, the time series are shorter, and privatisation and regulatory change from former planned economies is less comparable with change in industrial organisation elsewhere. We also limit our analysis to the electricity industry, a core public utility for most consumers. Government-owned providers of electricity were (and are) usually not loss makers in Western Europe, i.e. their average prices covered average costs (with a mark-up). In spite of cross-subsidies, comparison with pricing of private firms is more meaningful in electricity than in other sectors, where budgetary transfers may allow lower prices, e.g. public transport or water supply. Moreover, under market opening, public and private electricity firms actually compete for the same potential customers.

Our main research question is simple: Are consumer prices of electricity lower (after controlling for market opening, country and industry specific factors) in countries that implemented privatisation in the electricity industry? Previous empirical research shows that it is unlikely that there is a positive net benefit of a policy reform if consumers do

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not get a dividend from it, see e.g. Ugaz and Waddams Price (2003).[1] The empirical literature on the impact of reforms on consumer prices in the electricity sector provides mixed evidence. For example, Hattori and Tsutsui (2004) look at 19 OECD countries (1987–1999) and consider both industrial prices and the ratio between industrial/household prices. They find some support for privatisation and liberalisation as determining price decrease. Steiner (2000), however, in a study of 19 OECD countries (1986–1996), finds that privatisation (and time to it) increases prices, while unbundling and liberalisation have the opposite effect. Zhang et al. (2008) study electricity residential prices in 51 developing countries (1985–2000) and find no effects of the reforms. Martin and Vansteenkiste (2001) do not find an impact of liberalisation on prices, and find that public ownership increases prices in the EU15, in the very short period they consider (1995–2000). Gassner et al. (2009), in a detailed empirical study for the World Bank on 1200 utilities in 71 developing and transition countries over ten years, including publicly owned and private sector participated ones, find that privatisation does not have an impact on prices and investments by using differences-in-differences econometric techniques. Our paper contributes to this literature by explicitly considering dynamics, using time series longer than in earlier literature and data sources from international organizations.

The structure of the paper is the following: first, we briefly review some key facts about the reform and price trends in the European electricity industry (Section 2). Then we discuss earlier literature and introduce a simple conceptual model (Section 3). Hence, we present our empirical modelling strategy (Section 4), present and discuss the main limitations of the data used (Section 5), and illustrate our main results (Section 6). Finally, we draw our conclusions and discuss lines for further research (Section 7).

## 2. Reform and electricity price trends

As mentioned in the Introduction, the typical 'British-style' electricity reform package is characterised by privatisation, unbundling, regulation, and market opening. In the last two decades the EU has witnessed a considerable variability of policy combinations thereof. Thus we want to test separately the effects of privatisation against other dimensions of the reform package.

Electricity is a sector where the reforms started in the 1990s, with persistent differences in technologies and in the endowment of fuel resources across countries. The technology is similar across countries, but there are variations in dependency on a homogenous natural resource.

Public enterprises in the electricity sector were profit-makers in Western Europe, and usually had no difficulty in financing their investments, hence their pricing is usually not affected by government transfers, as in other network industries (e.g. railways), see Millward (2011) for long-run perspective.

The regulatory history of the electricity sector has been summarised in the Indicators of Regulation in Energy, Transport and Communications (ETCR), released (April 2009 version) by the OECD and covering years 1975–2007 (Conway and Nicoletti, 2006). ETCR database provides an industry measure that comes from the aggregation of different dimensions of the reforms, such as public ownership, vertical integration, market entry, which themselves come as an aggregation of further decomposition of each regulatory dimension. All these indices score from 0 to 6, under different headings and sub-headings. An industry characterised by full public ownership, vertical integration, no access to the industry except for the public operator scores 6 in the aggregated indicator, which comes as the average of the maximum score reached in all subindicators. At the other extreme, an industry that is operated by private operators only, with total unbundling of its production process and full market opening will score 0, the minimum.

Fig. 1 presents the history of electricity regulatory reforms in a concise way, where the average of the overall and public ownership ETCR score dynamics are reported. The downward pattern of the public ownership and overall ETCR score index emerges, with the latter being more pronounced than the former, meaning that other dimensions of the reform (namely, entry liberalisation and unbundling) had an even more pronounced decreasing dynamics. The electricity industry reform starting date was around late 1980s: while unbundling and entry regulation were forced by EU legislation, divestiture of public ownership was not yet implemented, although the path of the public ownership indicator is markedly decreasing especially since the end of the 1990s. Market structure in electricity is not reported in ETCR, but there is evidence elsewhere of a tendency towards oligopoly with a competitive fringe (CEC, 2007; Del Bo and Florio, 2012).

How did consumer electricity prices evolve since the end of the 1970s? Fig. 1 also depicts the median price of electricity for residential consumers across the EU15, using the longest time series available of average national prices, deflated using the yearly national consumer price index and setting at 100 the median price in 2000. It is worth noting that the downward price trend started well before the reform wave showed its first signs: about two thirds of the average price reduction happened before 1990, when the reforms started in the UK (the front runner of reforms in the EU15). Another reduction happened before 1996, when the first EU Directive was approved. After 2003, when the second EU directive was approved, the price started increasing, most likely due to the increasing cost of oil (and of natural gas, which is often indexed to oil prices).

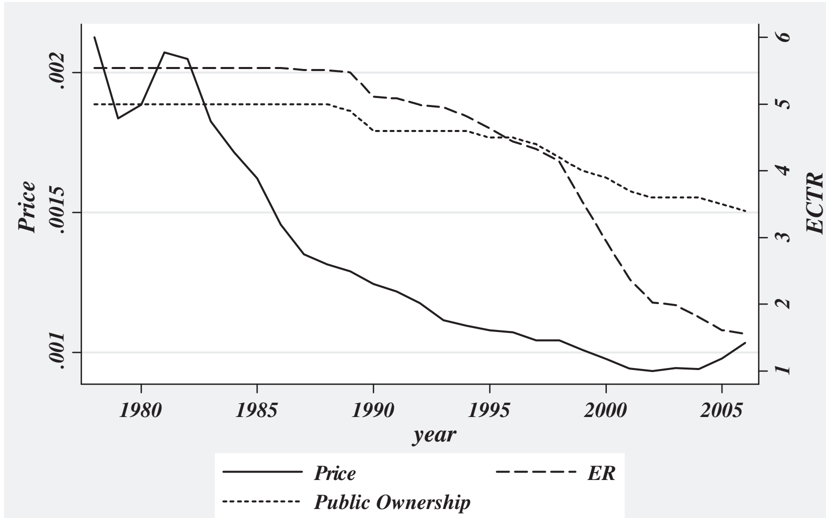
It is also informative to look at price figures deflated using the consumer price index for some relevant years in two key countries, the UK and France often regarded as at the two extremes of reform policy implementation (Table 1). In 1978 the standard deviation of electricity prices in the EU was wide, about as large as its average and prices paid in France and in the UK are equal and well below the EU15 mean. Since 1990 up until the end of the period considered, French prices tended to be lower and UK ones higher than the average, besides the convergence of prices across the EU15 as showed by the decreasing EU15-standard deviation.

The message from this example is twofold: first, relative prices show strong and different dynamics across countries; second, to study the impact of privatisation and liberalisation in the long-run and across countries we need to control for possible cost and demand shifters.

## 3. Earlier literature and conceptual framework

Public versus private ownership of utilities is a widely discussed theme in the years that we consider in this paper. The case for privatisation is reviewed, inter alia, by Bös (1991),Vickers and Yarrow (1993), Parker (1998), Newbery (2000), Florio (2004, 2013), Megginson (2005), Roland (2008). On the issue of the welfare impact of privatisation a seminal paper by Sappington and Stiglitz (1987) established the conditions for indifference between public and private ownership. They show that under different information structures a benevolent policy-maker who can write complete contracts achieves the same welfare outcomes of private owners. Schmidt (1996), suggests that the government is unable to get all the information needed to achieve the Sappington–Stiglitz result, while Shapiro and Willig (1990) focus on the private agenda of policy makers. Laffont and Tirole (1993) stress the trade-off that the managers face when they need to respond to private owners and to regulators. This is a multi-principal context in which privatisation can be socially beneficial if the objectives of managers and of shareholders are more aligned than the objectives of the manager and the regulator. The hypothesis that

[1] In the UK case it is possible that the main beneficiary have been firms and not directly consumers (see Domah and Pollitt, 2001; Newbery and Pollitt, 1997; Pollitt, 2012).




*Note: Price (source: IEA) deflated using the national CPI (source: WDI), at 2000 base price. Price scale on the on the left axis, ECTR indices scale on the right axis. ER and Public ownership are ETCR 0-6 scores for the whole industry and its public ownership dimension, respecively*

**Fig. 1.** Average price, overall and public ownership ETCR scores for the electricity industries over time.

privatisation is rooted in the limited commitment credibility of government does not provide a clear-cut answer to the question of the relative merits of public versus private ownership in a network industry. If privatisation enhances efficiency through information rents given to the agent, unit cost may decrease more than the mark-up on costs, but the same result may be achieved by a combination of public ownership, managerial discretion, and independent regulation. The distinction between privatisation and liberalisation is a core one, see Vickers and Yarrow (1993).

A simple conceptual model allows us to show how ownership and other regulatory reforms may have an impact on consumer prices. Ceriani and Florio (2010) and Florio (2013, Ch 3) discuss in greater detail the simple setting that we have in mind.

Let us consider a simplified market for electricity supply with a linear market demand curve: $p = d - bq$, where $d$ and $b$ are parameters, $p$ are prices and $q$ are quantities. To simplify, we set $b = 1$ and we also assume that variable costs are linear in output, so that total costs can be written as $c = vq + f$, where $v$ and $f$ are parameters. The electricity network is already existing, i.e. we assume that the core investment is a sunk cost, hence $f$ represents fixed operation and maintenance costs.

Assume now that this market is served by a vertically integrated public monopolist providing electricity services. To capture the idea that government ownership of the industry is inefficient, as in some of the above mentioned theoretical literature, the public monopolist's costs ($c_{pu}$) are assumed higher than those of a first best economy with parametric input prices, $c^* < c_{pu} = v\,(1 + a)q + f$, where $a > 0$ is a parameter reflecting inefficiency in the public provider, e.g. reflecting political rents, corruption, or excess employment in the government owned generation and distribution, a fact that has been empirically observed in the UK and elsewhere comparing 'before' and 'after' electricity privatisation histories, see Newbery and Pollitt (1997), Dal Bó and Rossi (2007). The inefficiency of the state-owned firm can also be related to fixed costs, but this is not our main concern here. If the electricity public corporation is instructed to maximize consumer surplus, under budgetary constraint, then price equals marginal costs (i.e. $p_{pu} = v(1 + a)$) and the public monopolist faces a loss equal to the fixed costs $f$. Hence, the government has to subsidize the public monopolist in order for the firm to remain economically viable. Alternatively, there may be a separate fixed charge paid by consumers.

In a different country (or in a different time) the public monopolist is privatised without imposing a price-cap regulation. The new shareholders instruct the management to maximize profits. This has two effects. As $a = 0$, private monopolist marginal costs ($c_{pr}$) are now equal to first best $c^* = c_{pr} = v$, perhaps by shedding excess labour. Given the linear demand assumed, the unregulated monopolist price is $p_{pr} = v(1 - z^{-1})^{-1}$, which implies[2] that $p_{pr} > p_{pu}$, if $(z - 1)^{-1} > a$, where $z$ is the absolute value of the demand elasticity. If this is the case, an unregulated efficient private monopolist might be beneficial to the consumer even without strong price regulation. However, as the price elasticity of electricity is usually well below unity (see Lijesen, 2007, Table 1 for a survey of estimates), the fixed charge paid by consumers would be large and unregulated privatisation would perhaps never be beneficial, even if the inefficiency of the public monopoly is high.

To counteract this, the government appoints a regulator, who is instructed to implement a price-cap as the incentive compatible (not necessarily optimal) mark-up above the first best market's price, allowing the reform to have a positive impact on consumers' welfare only if the mark-up is larger than public provider's inefficiency, $a$.

The third step of the British-style electricity reform is vertical disintegration of the industry (see Willner and Grönblom, 2012, for a wide review of the related issues). There are now two different

**Table 1**
Price trends and report scores for the EU15, France and the UK.

| | | 1978 | 1990 | 1995 | 2000 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| | | Electricity | | | | | | | |
| France | Price | 0.14 | 0.11 | 0.11 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 |
| | ETCR score | 6.00 | 6.00 | 6.00 | 4.28 | 3.61 | 2.61 | 2.61 | 2.11 |
| UK | Price | 0.14 | 0.13 | 0.10 | 0.11 | 0.09 | 0.10 | 0.10 | 0.12 |
| | ETCR score | 6.00 | 0.83 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| EU15-average | Price | 0.22 | 0.12 | 0.11 | 0.10 | 0.09 | 0.09 | 0.10 | 0.10 |
| | ETCR score | 5.54 | 5.11 | 4.64 | 3.16 | 2.13 | 1.94 | 1.73 | 1.67 |
| EU15-st. dev. | Price | 0.24 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | ETCR score | 0.61 | 1.36 | 1.57 | 1.54 | 1.05 | 0.96 | 0.82 | 0.81 |

Source: Authors' calculations using IEA, WDI and ETCR data.
Note: Prices in US$/KWh, converted into current euro using Eurostat €/USD exchange rate.

[2] This comes from the fact that the private monopolist fixes its price where $z > 1$.

players: one acting as a network owner with increasing returns to scale and marginal costs equal to zero and another with constant average and marginal costs. As observed by Pollitt (2008) unbundling the transmission and distribution networks from operations is not a free-lunch, as administration and transaction costs are not negligible in the electricity industry, particularly because of the limited opportunity of storage.

As usual, the operator will maximize his profits under the price-cap constraint, but now with the additional assumption than the unbundling inefficiency is lower than the mark-up. This will reduce the monopolistic mark-up, because of both higher marginal costs and because the price-cap does not allow the privatised monopolist to shift the burden to the consumer.

Privatisation and unbundling, however, were only preliminary steps aimed at market opening. If the government now instructs the regulator to offer a number of licences to new entrants, under full competition, as the number of the competitors increases, the decreasing share of total market output of each single firm drives the price in liberalised market ($p_{lib}$) close to first best, but the increasing inefficiency due to unbundling, drives it in the opposite direction.

Minimising the social cost of liberalisation, in turn, implies having solved complex technical issues. The unbundling inefficiency function is probably increasing in the number of players because of some special technological features of the electricity market.[3] Attacking these costs is possible through investment on the grid, storage of energy and of capacity, strategic reserves, etc. These costs may be shifted to the tax-payer or to the consumer in various tariff structures, but cannot be abolished.

Hence, this simple conceptual model shows why it is not self-evident whether privatisation, regulation or liberalisation each per se offers to consumers lower electricity prices than a well-managed vertically integrated public monopoly, or other combinations of the ingredients we have mentioned (for example, mixed oligopoly with price-cap regulation, etc.). The result would depend upon some parameters (in fact functions of other variables), which can be country-specific. More complex models of (strategic) oligopoly (see Willner and Grönblom, 2012) would add many important details, but the price outcome is perhaps even more uncertain. The cost–benefit analysis of liberalisation is also complex because of the need of a counterfactual scenario and because of general equilibrium effects. This uncertainty justifies a closer inspection of empirical evidence.

## 4. Our approach to the empirical analysis

The conceptual framework presented in the previous section, could be rephrased using a standard demand–supply structural model with the inclusion of regulatory variables. However, because of data limitation, the estimation of such a structural model is beyond the scope of this paper. Hence, the empirical analysis is based on the specification and estimation of a reduced form equation of retail electricity prices, as in several other papers in earlier literature, but with some innovations in the empirical approach (see below).

This specification allows us to address the following research question: is private ownership associated with lower consumer prices, after controlling for liberalisation? We want to test whether consumers actually pay less when we observe a reform of corporate ownership, after controlling for demand and cost shifters. We focus exclusively on consumer prices net of taxes: although taxation was a major driver of price increase in recent years (European Commission, 2012) its consideration would blur the picture of the impact of liberalisation reforms on consumer prices.

This research question tests hard 'objective' evidence on average prices only, as prices paid by individual consumers are unavailable in cross-country data sets. Moreover, the analysis of softer 'subjective' evidence of individual users' satisfaction with prices, while interesting from a policy point of view, may contain a different type of error if individuals are biased in their perceptions.[4]

As a first explorative estimation, we estimate the static panel model:

$$P_{it} = R'_{it}\beta + X'_{it}\gamma + \delta_t + \xi_i + \varepsilon_{it} \quad \text{with } i = 1,\ldots,I;\ t = 1,\ldots,T, \tag{1}$$

where $P_{it}$ is a measure of current net-of-tax (log) prices for country $i$ at time $t$, $R_{it}$ is a set of regulatory variables, which may include a score of the level of regulatory regime in the electricity industry or measures of entry regulation, public ownership, vertical integration, and $X_{it}$ is a set of control variables.[5]

Year fixed effects ($\delta_t$) are included to capture the common trend across the EU and common cyclical components in prices, aggregate or detailed measures of the level of privatisation and liberalisation of the sector and other macroeconomic variables. We also include country-fixed effects to control for time-invariant and country-specific characteristics.

Prices and control variables are log-transformed to interpret coefficients as elasticities and for increasing the fit of the regression model. The estimation of the country effect $\xi_i$ aims at taking into account time invariant differences among countries. To exploit the cross-country variation in the data and in particular to assess whether results regarding the association between prices and regulatory variables would change, we estimate also a set of between estimation panel models, by regressing the time-average of prices ($\overline{P}_i$) on the time-average of regulatory and control variables ($\overline{R}_i, \overline{X}_i$). Although this model is very likely to be inconsistent because of the correlation of the error term with the regressors, it allows us to assess the possible association between price and energy source variables.

Finally, following Blundell and Bond (1998, 2000) and Bond et al. (2003) we study the autoregressive (AR) properties of the average consumer price for each industry. As we find evidence of prices following AR(1) processes (cf. Table A1 in the Appendix A), the econometric analysis of consumer prices is performed by using dynamic panel data models, i.e. including among regressors also the lagged dependent variable for explaining the strong persistence of prices. The dynamic panel model for log-price levels is:

$$\begin{aligned} P_{it} &= \alpha P_{i,t-1} + R'_{it}\beta + X'_{it}\gamma + \delta_t + \varepsilon_{it} \\ \varepsilon_{it} &= (\xi_i + \nu_{it}) \text{ with } i = 1,\ldots,I; \quad t = 1,\ldots,T. \end{aligned} \tag{2}$$

A key assumption of this kind of models is that of independence of the idiosyncratic disturbances ($\nu_{it}$) across countries. We treat the country fixed-effects ($\xi_i$) as stochastic, which implies that they are correlated with the lagged dependent variable ($P_{i,t-1}$), unless the distribution of the $\xi_i$ is degenerate. We also allow the control variables ($X_{it}$) and the regulatory variables ($R_{it}$) to be correlated with the country effect $\xi_i$.[6]

?

The assumption of stochastic individual effects implies that they are correlated by definition with $P_{it}$, and possibly also with $X_{it}$ and $R_{it}$. Hence, we estimate our model using Generalised Method of

[3] See Fraquelli et al. (2005) for a discussion.

[4] For a discussion of consumers' perception of electricity prices, see Fiorio and Florio, 2011.

[5] Although we tested for several demand and sector specific variables, including input costs and efficiency indicators, we retained only those which proved statistically significant in at least one of the specification considered.

[6] By maintaining that the $v_{it}$ component of the error term is serially uncorrelated, we assume that $X_{it}$ is strictly exogenous (i.e. uncorrelated with all past, present and future realisation of $v_{it}$). As for the set of reform variables $R_{it}$, we assume that they might be correlated with the unobserved error term but that, due to the political and decisional process involved, they react with some lag to changes in $v_{it}$. In other words, we assume that $R_{it}$ is predeterminate (i.e. $R_{it}$ and $v_{it}$ are uncorrelated, but $R_{it}$ may be correlated with $v_{i,t-1}$ and earlier shocks).

Moments (GMM) which, by using extra moment conditions, produce consistent and efficient estimates, coping with endogeneity of the lagged dependent variable.[7]

In all our GMM estimates, we use a one-step GMM estimator, similarly to most applied work in this area as simulation studies have suggested very modest efficiency gains from using the two-step version, even in presence of considerable heteroskedasticity (Arellano and Bond, 1991; Blundell and Bond, 1998; Blundell et al., 2000).

We mainly use the Arellano and Bond (1991) autocorrelation test for assessing whether autocorrelation in the idiosyncratic disturbance term $v_{it}$ would render some lags invalid as instruments, which is a key identifying restriction in dynamic panel data models estimated using GMM.[8]

Finally, we also tested our estimates for robustness excluding one country from the sample at a time, assessing whether the results are strongly dependent on the inclusion of one particular country.

## 5. The data

The primary source for the average residential consumer prices net of tax is the International Energy Agency (IEA), whose time-series starts in 1978, providing over 30 time series (some summary statistics are provided in the Appendix A, Table A3). The IEA carefully defines the average unit value of electricity for households, which we use here. Electricity is supplied under a multitude of contract or tariff conditions which link the prices to the quantity delivered, the continuity of the supply, load factors and the diurnal pattern of use. The contracts or tariffs may also include a fixed charge component. However, when seeking a representative overall price of electricity for broad sectors such as households, the IEA selects the average unit value, which is obtained either from utilities as average revenue per unit delivered or from households as average expenditure per unit purchased. These average unit values are only available on an annual basis. For more details, see IEA (2012).

The only alternative data source available for a EU15-wide analysis would be the Eurostat, which however is available for a much shorter time period as it starts at best in 1991, making the estimation of GMM models very problematic. It is also worth noting that IEA and Eurostat net-of-tax electricity prices for households for the overlapping period are highly correlated (simple correlation coefficient $= 0.814$).[9]

Ideally our empirical analysis should be based on individual prices paid by single consumers with a knowledge of their level of consumption but this would limit our analysis on single countries as, to the best of our knowledge, there is no harmonised dataset providing such an information. It is worth stressing that even using aggregated data only, any economic analysis of electricity reforms by consumer groups is strongly limited by data availability, as IEA provides information on average prices only and Eurostat, besides collecting data on five different classes of (half-year) electricity consumption, provides them for (roughly) all EU15 countries only since 2005.[10]

As for the regulatory reform variables, including measures of entry regulation, public ownership and vertical integration, we used data provided by the ECTR data set. These data have a yearly frequency, are available since 1975 and up to 2007 and present detailed information allowing one to capture the industry-specific trends of reforms in the electricity sector. As mentioned in Section 2, ETCR score, going from 0 to 6, is computed as a weighted average of public ownership, vertical integration, market structure and entry regulation scores, by assigning a cardinal measure to variables that are in itself ordinal. Hence, we use the industry ETCR score (*ER*) as an indicator of the overall reform, but we also introduce our own coding of subindicators. In particular, we defined dummy variables preserving the ordinal nature of the reform dimensions measures. For instance, for each industry, we defined a dummy variable for public ownership equal to 1 if the industry is "public" and zero otherwise (*ERpo_d*). A dummy variable for entry regulation equal to 1 if there is "no third party access, full entry regulation" and zero otherwise (*ERen_d*). A dummy variable for vertical integration equal to 1 if the industry is "vertically integrated" and zero otherwise (*ERvi_d*). This approach avoids any possible measurement bias with cardinalisation as in the original ETCR scores (for more details on the variable definition of the original ECTR database and our coding, refer to Table 2).

## 6. Results

Table 3 shows the results of the estimation of the static panel model (1), where different variables capturing various dimension of electricity sector reforms are included. In the first column we only control for the ETCR score, which is significantly negative suggesting that the reform process as a whole, by reducing the reform score, is associated to an increasing average price paid by the EU average household. Hence, to investigate this result further, we broke down the ECTR score in its main component, namely public ownership, vertical integration and entry regulation. The second column shows that while vertical integration dummy is not significant (and in fact it never is in all model specifications we used), both public ownership and high entry regulation are associated with lower prices. By dissecting the entry regulation dummy in its main components, columns (3)–(5) suggest that it is mostly the variable indicating whether consumers can switch providers (*ERen3_d*) that is significantly associated with prices and driving results as for entry regulation.

Although given data availability we cannot rule out possible bias due to spurious correlation and omitted variables, it is interesting to notice that some variables remain consistently significantly negative, namely the public ownership dummy, regardless of the empirical specification used.

As for other control variables included, prices are positively associated with per capita GDP (*lMWgdppc*) and negatively with imports (*lEAimports*) and residential consumption (*lEArescons*). In the last two columns of Table 3 we also introduced the log of consumer price index (*lMWcpi*), which is highly correlated with per capita GDP (*lMWgdppc*), and it presents the expected significant positive sign with no relevant effect on the coefficient of the public ownership variable. Interestingly, the entry regulation dummy becomes insignificant in column (7), rising some doubts about the robustness of its association with prices. Finally, the variable measuring the amount of electricity produced by using combustible fuel (*lEAscmbf*) is never statistically significant, which is not particularly surprising as its variability is very low within countries. This is a consequence of the fact that fuel price is internationally determined and that the price component of the tariff

[7] In fact, as no external instrument is usually available outside the immediate data set, an alternative to OLS and Within estimates is to either transform the data to eliminate the individual effects or find some instruments that are orthogonal with the error term but not with endogenous regressors. Arellano and Bond (1991) suggested transforming the data in first-difference eliminating the fixed effect, although the lagged dependent variable remains potentially endogenous, and predetermined variables such as $\Delta R_{it}$ become potentially endogenous because they may also be related to $v_{i,t-1}$. However, longer lags of the endogenous regressors are orthogonal to the error and can provide additional moment conditions working in the GMM framework. Of course, also the orthogonality of the exogenous variables with the transformed error term is exploited and corresponding moment conditions included in all GMM estimations.

[8] The test of *r*-order serial correlation is asymptotically normally distributed under the null of zero serial correlation. Arellano and Bond (1991) find that their test has greater power than the Sargan/Hansen test to detect lagged instruments being invalid due to autocorrelation.

[9] IEA monetary variables, which are expressed in US$, were converted into euro using the Eurostat euro/US$ exchange rate. Eurostat price data refers to an average yearly consumption of 3500 kWh.

[10] From 1985 to 1992 data by different consumptions groups were available for Luxembourg, Belgium and Denmark only. Italian data since 1993, British (discontinuously) since 1999, French ones since 2002, just to name a few.

**Table 2**
The ETCR indicator for the electricity industry with our coding.

| Electricity | Original ETCR coding | | | Our coding | |
|---|---|---|---|---|---|
| | Country scores 0-6 | | Sector indic. | Binary variable 0-1 | |
| | Question weights | Weights by theme | Our label | Coding | Our label |
| Public ownership: | | | | | |
| What is the ownership structure of the largest companies in the generation, transmission, distribution, and supply segments of the electricity industry? (ERpo1) | 1 | 1/3 | | 1 if ownership is public | *ERpo_d* |
| Entry regulation: | | | | | |
| How are the terms and conditions of third party access (TPA) to the electricity transmission grid determined? (ERen1)* | 1/3 | | | | |
| Is there a liberalised wholesale market for electricity (a wholesale pool)? (ERen2)* | 1/3 | 1/3 | *ER* | 1 if wholesale market for elect. is not liberalised & consumption threshold is larger than 1MWatts | *ERen_d* |
| What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier ? (ERen3)* | 1/3 | | | | |
| Vertical integration: | | | | | |
| What is the degree of vertical separation between the transmission and generation segments of the electricity industry? (ERvi1) | 1/2 | | | | |
| | | 1/3 | | 1 if overall degree of vertical integration in the industry is mixed or integrated. | *ERvi_d* |
| What is the overall degree of vertical integration in the electricity industry? (ERvi2) | 1/2 | | | | |

determined in wholesale markets is related to oil and gas price as almost everywhere the marginal technology is thermoelectric.[11]

Table 4 presents the result of the estimation of various specifications of the dynamic panel data model (2) for the electricity prices. The first column provides a test of the reform as a whole, estimating model (2) where the reform variable $R$ is the ETCR sector score ranging from 0 to 6. In the following columns, we use as reform variables the set of dichotomous dummy variables, as described in Section 5. All models are estimated using GMM.

Due to the small dimension of the whole panel, and following Blundell and Bond (2000) who discuss the possibility that the error term might have a small degree of autocorrelation due to measurement errors, we estimate these models using as instruments the three most recent lags of the dependent variable starting from period $t-3$. All estimated models pass the key identification tests allowing for zero second-order autocorrelation of residuals, as well as the Sargan test for over-identifying restrictions. All models are estimated using robust estimation as tests of homoskedasticity of residuals always rejects the null.

The highly significant lagged dependent variable sheds doubt over similar panel data models in earlier literature without a dynamic specification, whose estimates are very likely to be affected by omitted variable bias, as discussed in the Appendix A (Table A2).

It is interesting to notice that the lagged dependent variable is highly significant also after inclusion of year fixed-effects, regulatory variables and other controls. If the ETCR score, ranging from 0 (full privatisation, unbundling and liberalisation) to 6 (no privatisation, vertical integration and no free entry in the industry), is included in the regression testing whether the reform package as a whole had any effect on average

[11] We are grateful to an anonymous referee for suggesting this explanation.

**Table 3**
Within (fixed-effect) estimation of a static panel.
Source: Authors' calculations using IEA, WDI source data. IEA data used for price series.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | FE | FE | FE | FE | FE | FE | FE |
| *ER* | $-0.032^{***}$ | | | | | | |
| | (0.000) | | | | | | |
| *ERpo_d* | | $-0.124^{***}$ | $-0.131^{***}$ | $-0.137^{***}$ | $-0.137^{***}$ | $-0.093^{***}$ | $-0.123^{***}$ |
| | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *ERvi_d* | | 0.035 | 0.039 | 0.035 | 0.037 | 0.038 | 0.047 |
| | | (0.212) | (0.168) | (0.201) | (0.190) | (0.176) | (0.148) |
| *ERen_d* | | $-0.083^{***}$ | | | | $-0.091^{***}$ | $-0.016$ |
| | | (0.004) | | | | (0.001) | (0.614) |
| *ERen1_d* | | | $-0.039^{*}$ | | | | |
| | | | (0.085) | | | | |
| *ERen2_d* | | | 0.001 | | $-0.007$ | | |
| | | | (0.953) | | (0.766) | | |
| *ERen3_d* | | | $-0.081^{***}$ | $-0.081^{***}$ | $-0.079^{***}$ | | |
| | | | (0.001) | (0.001) | (0.001) | | |
| *lEAscmbf* | 0.026 | 0.011 | 0.011 | 0.013 | 0.012 | $-0.008$ | 0.033 |
| | (0.161) | (0.567) | (0.555) | (0.498) | (0.520) | (0.653) | (0.120) |
| *lEAimports* | $-0.014^{***}$ | $-0.012^{***}$ | $-0.012^{***}$ | $-0.012^{***}$ | $-0.012^{****}$ | $-0.011^{***}$ | $-0.003$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.248) |
| *lEArescons* | $-0.263^{***}$ | $-0.261^{***}$ | $-0.255^{***}$ | $-0.261^{***}$ | $-0.260^{***}$ | $-0.366^{***}$ | $-0.247^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *lMWgdppc* | $0.557^{***}$ | $0.515^{***}$ | $0.504^{***}$ | $0.491^{***}$ | $0.496^{***}$ | $0.517^{***}$ | |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | |
| *lMWcpi* | | | | | | $0.151^{***}$ | $0.132^{***}$ |
| | | | | | | (0.000) | (0.000) |
| Constant | $2.168^{***}$ | $2.025^{***}$ | $1.956^{***}$ | $1.894^{***}$ | $1.922^{***}$ | $2.668^{***}$ | $-1.485^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.005) |
| Observations | 417 | 417 | 417 | 417 | 417 | 404 | 404 |
| R-squared | 0.835 | 0.839 | 0.842 | 0.840 | 0.840 | 0.842 | 0.786 |
| Number of country | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

Dep. var.: log average price for electricity supply.
Variable definitions:
*lEAprinet*: log-Electricity net-of-tax price for households, submitted to the IEA Secretariat by Administrations (in €/unit) (Source: IEA; (a)).
*lEAscmbf*: log-Electricity source: Total Combu. Fuels (GWh/Tj) (IEA).
*lEAimports*: log-Electricity import (GWh) (Source: IEA; (a)).
*lEArescons*: log-Electricity residential consumtion (GWh) (Source: IEA; (a)).
*lMWgdppc*: log-Nominal GDP (billion of euro) (Source: WDI; (a)).
*ER*, *ERpo_d*, *ERen_d*, *ERvi_d*: See Table 2.
(a) Original data are in US$ and were converted to € using Eurostat euro/USD average yearly exchange rate.
p-values in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Year dummies included in all models.

prices, one could conclude that no statistically significant effect is found. If, instead of the ETCR score, a dummy variable for each of the three dimensions of the electricity industry reform is included, it emerges that only public ownership variable (*ERpo_d*) presents a consistently significant coefficient, reducing average price by roughly 0.3 (log) points. Vertical integration, which is strongly correlated with public ownership, is never statistically significant. Entry regulation is significant at the 10% significance level although it is mainly the freedom of choice of providers that drives this effect (*ERen3_d*). Interestingly, the coefficient is negative suggesting that allowing consumers to choose their provider is negatively correlated with actual price paid. In fact providers might decide to moderate price rises to attract new customers and to reduce the likelihood that some of their customers switch to other providers. Other control variables are not significantly correlated with average log prices, with the exception of per capita GDP, suggesting that electricity is a normal good.

Hence, decomposing the ETCR score into 0–1 variables, we find that evidence on average price is consistent with evidence on consumers' perception discussed in Fiorio and Florio (2011), in particular as far as public ownership is concerned.

### 6.1. Diagnosis and robustness checks

Since Bound et al. (1995) it is well known that weak instruments can provide inconsistent estimates. Hence, similarly to Blundell and Bond (2000), we estimate a reduced form regression of the first difference $\Delta\log(price_{t-1})$ on $\log(price_{t-2}),\log(price_{t-3}),\ldots,\log(price_{t-20})$. A small coefficient of determination ($R^2$) in any of these regressions and a Wald test of slope coefficients jointly equal zero would signal a weak instrument set. For the electricity sector we find $R^2 = 0.288$, which lets us conclude that the lagged log prices in levels are acceptable instruments for the endogenous lagged first difference. Moreover, the null hypothesis of all instruments being jointly zero is rejected at any reasonable confidence level.

In Section 6 we used GMM as the assumption of stochastic individual effects implies that they are correlated by definition with the dependent variable, $P_{it}$, and possibly also with other covariates. If so, Ordinary Least Square (OLS) estimator of $\{\alpha,\beta,\gamma\}$ in the level equations of model (1) is inconsistent, and this correlation remains even for $T,N \to \infty$. A Within estimator would eliminate the main source of OLS inconsistency, i.e. the country fixed effect, $\eta_i$, however it does not completely solve the problem. In fact, for a small $T$, the Within transformation induces a correlation between the transformed lagged dependent variable and the transformed error term, producing a biased estimator (Nickell, 1981).

Notwithstanding their biased nature, and mainly as a robustness check, we estimated the dynamic panel model (2) also using OLS and Within.

Table 5 shows OLS and Within estimates for the electricity price model, respectively. Compared to the GMM results and using OLS,

**Table 4**
GMM estimation of dynamic panels for electricity prices.
Source: Authors' calculations using IEA, WDI source data. IEA data used for price series.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | GMM | GMM | GMM | GMM | GMM |
| *L.lEAprinet_kw* | 0.854*** | 0.414*** | 0.407*** | 0.428*** | 0.414*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *ER* | 0.003 | | | | |
| | (0.690) | | | | |
| *ERpo_d* | | −0.376*** | −0.356*** | −0.350*** | −0.366*** |
| | | (0.000) | (0.000) | (0.000) | (0.000) |
| *ERen_d* | | −0.106* | | | |
| | | (0.072) | | | |
| *ERvi_d* | | 0.099 | 0.079 | 0.037 | 0.066 |
| | | (0.233) | (0.393) | (0.598) | (0.462) |
| *ERen1_d* | | | −0.043 | | |
| | | | (0.483) | | |
| *ERen2_d* | | | −0.015 | | −0.024 |
| | | | (0.741) | | (0.596) |
| *ERen3_d* | | | −0.098* | −0.100** | −0.092* |
| | | | (0.073) | (0.049) | (0.088) |
| *lEAscmbf* | 0.025** | 0.016 | 0.021 | 0.023 | 0.021 |
| | (0.011) | (0.517) | (0.408) | (0.354) | (0.409) |
| *lEAimports* | 0.000 | −0.000 | −0.000 | −0.000 | −0.000 |
| | (0.720) | (0.913) | (0.900) | (0.936) | (0.917) |
| *lEArescons* | −0.022** | 0.002 | −0.008 | −0.007 | −0.005 |
| | (0.012) | (0.948) | (0.805) | (0.820) | (0.870) |
| *lMWgdppc* | 0.016 | 0.231*** | 0.215*** | 0.225*** | 0.227*** |
| | (0.274) | (0.000) | (0.000) | (0.000) | (0.000) |
| Year fixed-effects | Yes | Yes | Yes | Yes | Yes |
| Constant | −0.292** | −0.676** | −0.683** | −0.612** | −0.647** |
| | (0.026) | (0.011) | (0.011) | (0.015) | (0.014) |
| Observations | 402 | 402 | 402 | 402 | 402 |
| Number of countries | 15 | 15 | 15 | 15 | 15 |
| ar1p | 0.001 | 0.052 | 0.055 | 0.037 | 0.047 |
| ar2p | 0.281 | 0.952 | 0.733 | 0.735 | 0.787 |
| sarganp | 0.064 | 0.257 | 0.201 | 0.188 | 0.205 |

Dep. var.: log average price for electricity supply.
Notes: Robust p-values in parentheses. Year dummies included in all models.
ar1p and ar2p report the p-values of tests for first-order and second-order serial correlation, asymptotically $N(0,1)$ under the null of no autocorrelation. sarganp reports the p-value of the Sargan test for overidentifying restrictions, under the null of valid moment conditions.
GMM results are one-step estimates with heteroskedasticity-consistent standard errors (in parentheses) and test statistics.
Instruments used in all GMM equations include dependent variable at lags $t-3$, $t-4$, $t-5$, the predetermined regulatory variable (at time $t-1$ and earlier) and exogenous variables.
Variable definitions: see Table 3.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$

public ownership is now not statistically significant as most of the variability is now captured by the lagged dependent variable, which is estimated with a pointwise value very close to one. However, when Within methods are used instead, the lagged dependent variable coefficient reduces in magnitude and the coefficient of public ownership is found to be negative with p-values well below 10%, confirming what has been found using GMM. This result is particularly reassuring as the Within transformation, relying on a relatively long time series ($T_i \geq 20$, for all $i$), sweeps out most of the causes of endogeneity, hence of the source of inconsistency.

Finally, as a further robustness check, we tested our estimates excluding one country from the sample at a time, for assessing whether the results are strongly dependent on the inclusion of one particular country. Results, presented in Table 6, show that although the magnitude of some significant coefficient slightly changed the positive correlation of per capita GDP remains as well as the negative correlation of the dummy for public ownership with prices. The negative correlation between the no-free-entry dummy (*ERen_d*) and prices remains statistically significant in only 6 out of 15 samples.

Although we aimed at coping with endogeneity of the lagged dependent variable one may wonder whether log electricity prices are just spuriously correlated with regulatory variables. In fact, the period under analysis is one of sharply rising energy input prices at a time when public ownership is falling. Even recalling that the electricity industry never needed structural public transfers from the public budget, we could have only provided evidence showing that in countries with private ownership prices increased less. But it could also be that the preservation of public ownership occurred where a prevalence of hydro and nuclear source could avoid passing on price increases when commodity prices for gas and coal were rising and public ownership prevented exposing these systems to the need to adjust prices to the marginal cost of energy via efficient market-based trading.[12] This scenario, if correct, would not argue against privatisation, and would simply explain why consumers might be happier with the lower prices induced by a combination of hydro and nuclear generation and lack of pressure to adjust prices to the market level. In periods of falling commodity prices we might well observe the opposite result for the opposite reasons. The best we could do for attempting a reply to this objection would be to use data on energy source composition. These data are available only by the Eurostat and not earlier than 1991, i.e. significantly reducing the time dimension of the panel and preventing us to use the GMM toolkit. Moreover, considering that energy source composition was very stable throughout the whole period and energy composition would be dropped in a within estimation model, we estimated a simple between regression where each country average log price is regressed on average regulatory variables and a dummy indicating the share of energy produced by nuclear and hydroelectric sources.

Table 7 shows that countries where at least 10% of nuclear energy is used to produce electricity (i.e. for Belgium, Germany, Spain, France, UK, Finland and Sweden) experienced more than 20% lower average prices and, notwithstanding our concerns about inconsistency of coefficient estimations due to the correlation of regressors and the error terms, the public ownership dummy remains negatively associated with prices.

Finally, we also tested the inclusion of Brent oil price given its strong correlation with other energy input prices. This additional variable does not affect the negative correlation between average household electricity prices and public ownership dummy variable, nor the main results regarding other included variables.[13]

## 7. Concluding remarks and policy implications

In the last two decades, electricity reforms have been often proposed as a unique policy package that should include privatisation, vertical disintegration, and liberalisation. We contribute to the empirical literature on the impact of reforms on consumer prices by disentangling the ownership effect, after controlling for other reforms. Differently from all previous studies, we explicitly consider dynamics, use time series longer than in earlier literature, and data sources from international organisations.

Our discussion in Section 3 shows that if a public enterprise is very inefficient, a privatised monopoly or oligopoly, even without price regulation, can offer lower prices than the vertically integrated

[12] For the risk incurred by firms exposed to high levels of fixed investments in the electricity industry, see the recent debate in the UK following the White Paper by the British government (Florio, 2013, Ch. 5).

[13] Although estimate results are not produced here for matter of space, they could be provided upon request.

**Table 5**
Robustness checks for the electricity price model. Dynamic panel estimated using OLS and Within methods.

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | Within | OLS | Within | OLS | Within | OLS | Within | OLS | Within |
| *L.lEAprinet_kw* | 0.956$^{***}$ | 0.756$^{***}$ | 0.957$^{***}$ | 0.747$^{***}$ | 0.956$^{***}$ | 0.742$^{***}$ | 0.958$^{***}$ | 0.744$^{***}$ | 0.956$^{***}$ | 0.744$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *ER* | 0.000 | −0.005 | | | | | | | | |
| | (0.938) | (0.261) | | | | | | | | |
| *ERpo_d* | | | 0.003 | −0.027$^{*}$ | 0.002 | −0.031$^{*}$ | 0.003 | −0.032$^{**}$ | 0.002 | −0.032$^{**}$ |
| | | | (0.716) | (0.077) | (0.751) | (0.055) | (0.670) | (0.043) | (0.761) | (0.046) |
| *ERvi_d* | | | −0.008 | 0.018 | −0.010 | 0.019 | −0.006 | 0.018 | −0.010 | 0.019 |
| | | | (0.562) | (0.292) | (0.498) | (0.262) | (0.639) | (0.286) | (0.490) | (0.273) |
| *ERen_d* | | | 0.002 | −0.031$^{*}$ | | | | | | |
| | | | (0.880) | (0.082) | | | | | | |
| *ERen1_d* | | | | | −0.001 | −0.009 | | | | |
| | | | | | (0.911) | (0.536) | | | | |
| *ERen2_d* | | | | | 0.010 | −0.002 | | | 0.010 | −0.004 |
| | | | | | (0.465) | (0.889) | | | (0.469) | (0.789) |
| *ERen3_d* | | | | | −0.008 | −0.029$^{*}$ | −0.004 | −0.029$^{**}$ | −0.008 | −0.028$^{*}$ |
| | | | | | (0.583) | (0.057) | (0.744) | (0.044) | (0.581) | (0.061) |
| *lEAscmbf* | 0.010$^{**}$ | −0.004 | 0.010$^{**}$ | −0.009 | 0.010$^{**}$ | −0.009 | 0.010$^{**}$ | −0.008 | 0.010$^{**}$ | −0.008 |
| | (0.040) | (0.722) | (0.043) | (0.451) | (0.040) | (0.463) | (0.043) | (0.493) | (0.041) | (0.478) |
| *lEAimports* | −0.000 | −0.003$^{**}$ | 0.000 | −0.002$^{*}$ | 0.000 | −0.003$^{*}$ | 0.000 | −0.002$^{*}$ | 0.000 | −0.002$^{*}$ |
| | (0.944) | (0.049) | (0.981) | (0.070) | (0.990) | (0.061) | (0.969) | (0.072) | (0.990) | (0.071) |
| *lEArescons* | −0.010$^{*}$ | −0.100$^{***}$ | −0.010$^{*}$ | −0.101$^{***}$ | −0.010$^{*}$ | −0.101$^{***}$ | −0.010$^{**}$ | −0.102$^{***}$ | −0.010$^{*}$ | −0.102$^{***}$ |
| | (0.055) | (0.000) | (0.051) | (0.000) | (0.052) | (0.000) | (0.049) | (0.000) | (0.051) | (0.000) |
| *lMWgdppc* | −0.004 | 0.151$^{***}$ | −0.004 | 0.153$^{***}$ | −0.004 | 0.150$^{***}$ | −0.004 | 0.145$^{***}$ | −0.004 | 0.147$^{***}$ |
| | (0.663) | (0.000) | (0.671) | (0.000) | (0.663) | (0.000) | (0.669) | (0.000) | (0.665) | (0.000) |
| Year fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Constant | −0.063 | 1.137$^{***}$ | −0.056 | 1.172$^{***}$ | −0.057 | 1.150$^{***}$ | −0.052 | 1.135$^{***}$ | −0.057 | 1.146$^{***}$ |
| | (0.249) | (0.001) | (0.321) | (0.000) | (0.312) | (0.000) | (0.353) | (0.000) | (0.306) | (0.000) |
| Observations | 402 | 402 | 402 | 402 | 402 | 402 | 402 | 402 | 402 | 402 |
| ar1p | 0.171 | 0.0240 | 0.163 | 0.042 | 0.159 | 0.043 | 0.170 | 0.041 | 0.157 | 0.041 |
| ar2p | 0.815 | 0.583 | 0.800 | 0.665 | 0.779 | 0.679 | 0.781 | 0.683 | 0.779 | 0.683 |

Dep. var.: log average price for electricity supply. Robust p-values in parenthesis.
Variable definitions: see Table 3.
$^{***}$ $p < 0.01$.
$^{**}$ $p < 0.05$.
$^{*}$ $p < 0.1$.

public monopoly, because on balance its allocative inefficiency may be less than its cost savings. We find, however, that this is unlikely in Western European countries in the around thirty years that we consider.

While we have been able to identify a clear ownership effect, the overall evidence on the correlation of liberalisation reforms with prices is mixed. Public ownership seems to have capped residential electricity prices more than regulated competition in Western Europe, probably because of illiquid markets, inadequate regulation or both. We cannot rule out, with the available data, subtle dynamic issues of correlation of public ownership with technology adoption. Further research should also identify the role of different governance and regulatory mechanisms if detailed regulatory information became available across countries. As for technology adoption, however, the ownership effect that we have identified is still statistically significant when hydro and nuclear generation are controlled for (using Eurostat data). Given data availability, there is in any case evidence that consumer prices are lower in countries where public ownership has been preserved, and simple inspection of the data suggests that public ownership in the electricity industry is not associated with less market opening. Hence, we claim that our empirical analysis is novel and more appropriate to our research question than previous approaches.

In terms of policy implications, this suggests that when there is a tradition of reasonably effective management in the public sector, for example in the Scandinavian countries, or in France, public ownership can still play a role in protecting consumers from oligopolistic exploitation in electricity supply. This role must be, however, assessed case by case, looking at the specific institutional environment, and a rigid policy reform package seems not the best approach.

There are two more specific policy implications. First, while earlier reformers hoped that price caps were to be removed with full liberalisation, we suggest that under privatisation, continued monitoring and regulation of electricity prices for household should be a permanent feature, because productivity gains are not easily passed to consumers.[14] Second, we suggest that privatisation is not a panacea, and that the European Union must remain neutral about public ownership.

Thus, in our view article 295 of the EC Treaty[15] is a wise provision, in that it delegates to member states to decide whether in their national conditions public versus private provision is still an option to achieve certain objectives in the public interest.

In some countries and for some industries having public provision or a publicly owned network or a range of different arrangements (part-privatisation, mixed oligopoly, mutual ownership, etc., see Haney and Pollitt (2013) for a review of recent models of public ownerships in electricity) should be allowed without interference by the EU, as for article 295 of the Treaty, provided that (a) borders are open for capital investment and for trade, with the only limitation of national security of supply; and that (b) any citizen is given the concrete right and opportunity to pick up the best possible deal in the European economic space.

[14] Particularly to most vulnerable ones, as found by Poggi and Florio (2010).

[15] In fact, Article 295 of the EC Treaty states: "This Treaty shall in no way prejudice the rules in Member States governing the system of property ownership". This article was included in the 1957 Treaty to allow nationalisation of certain industries, and has not been changed over a half century.

**Table 6**
Robustness checks of GMM models of average price for electricity.

| Excluded country | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Belgium | Denmark | Germany | Greece | Italy | Spain | France | Ireland | Luxembourg | Netherlands | Portugal | Great Britain | Finland | Sweden | Austria |
| *L.lEAprinet_kw* | 0.420*** | 0.533*** | 0.441*** | 0.438*** | 0.296*** | 0.466*** | 0.465*** | 0.443*** | 0.438*** | 0.416*** | 0.211** | 0.384*** | 0.367*** | 0.453*** | 0.510*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.007) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.036) | (0.000) | (0.001) | (0.000) | (0.000) |
| *ERpo_d* | −0.373*** | −0.225*** | −0.335*** | −0.477*** | −0.432*** | −0.337*** | −0.350*** | −0.370*** | −0.353*** | −0.374*** | −0.266*** | −0.351*** | −0.356*** | −0.355*** | −0.230*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *ERen_d* | −0.106* | −0.055 | −0.084 | −0.065 | −0.175*** | −0.097* | −0.070 | −0.086 | −0.041 | −0.099* | 0.017 | −0.093* | −0.148** | −0.083 | −0.076 |
| | (0.080) | (0.239) | (0.157) | (0.279) | (0.003) | (0.091) | (0.203) | (0.138) | (0.537) | (0.098) | (0.765) | (0.097) | (0.025) | (0.225) | (0.172) |
| *ERvi_d* | 0.106 | 0.041 | 0.083 | 0.121 | 0.104 | 0.037 | 0.062 | 0.062 | −0.045 | 0.105 | 0.049 | −0.164 | 0.126 | 0.084 | −0.041 |
| | (0.216) | (0.420) | (0.302) | (0.171) | (0.244) | (0.521) | (0.446) | (0.453) | (0.637) | (0.188) | (0.501) | (0.173) | (0.137) | (0.328) | (0.501) |
| *lEAscmbf* | 0.017 | 0.037 | 0.018 | −0.006 | 0.002 | 0.020 | 0.020 | 0.020 | 0.004 | 0.021 | 0.043** | 0.029 | 0.012 | 0.008 | 0.027 |
| | (0.514) | (0.102) | (0.470) | (0.831) | (0.932) | (0.425) | (0.439) | (0.429) | (0.913) | (0.404) | (0.044) | (0.247) | (0.658) | (0.759) | (0.253) |
| *lEAimports* | −0.000 | −0.001 | 0.000 | −0.000 | −0.001 | 0.000 | 0.001 | −0.000 | 0.001 | −0.001 | −0.001 | 0.001 | −0.001 | −0.000 | 0.001 |
| | (0.930) | (0.808) | (1.000) | (0.895) | (0.667) | (0.969) | (0.862) | (0.921) | (0.773) | (0.830) | (0.818) | (0.859) | (0.819) | (0.958) | (0.835) |
| *lEArescons* | 0.002 | −0.019 | −0.000 | 0.039 | −0.001 | −0.011 | −0.003 | −0.010 | −0.078 | −0.003 | 0.023 | −0.017 | 0.007 | 0.012 | −0.025 |
| | (0.950) | (0.463) | (0.997) | (0.273) | (0.977) | (0.705) | (0.915) | (0.750) | (0.145) | (0.917) | (0.385) | (0.558) | (0.817) | (0.698) | (0.362) |
| *lMWgdppc* | 0.230*** | 0.213*** | 0.221*** | 0.239*** | 0.236*** | 0.208*** | 0.232*** | 0.207*** | 0.283*** | 0.229*** | 0.397*** | 0.196*** | 0.245*** | 0.224*** | 0.202*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Year fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | | |
| Constant | −0.678** | −0.484** | −0.657** | −0.710** | −0.728** | −0.529** | −0.529** | −0.627** | 0.593 | −0.718*** | −1.130*** | −0.681*** | −0.718*** | −0.621** | −0.351 |
| | (0.013) | (0.028) | (0.011) | (0.013) | (0.013) | (0.028) | (0.035) | (0.021) | (0.248) | (0.009) | (0.000) | (0.009) | (0.006) | (0.021) | (0.119) |
| Observations | 380 | 375 | 374 | 375 | 374 | 375 | 374 | 374 | 374 | 374 | 374 | 374 | 374 | 383 | 374 |
| Number of countries | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| ar1p | 0.056 | 0.042 | 0.049 | 0.073 | 0.078 | 0.036 | 0.041 | 0.033 | 0.072 | 0.052 | 0.219 | 0.110 | 0.057 | 0.042 | 0.038 |
| ar2p | 0.934 | 0.842 | 0.966 | 0.760 | 0.341 | 0.756 | 0.950 | 0.908 | 0.759 | 0.781 | 0.549 | 0.153 | 0.851 | 0.840 | 0.681 |
| sarganp | 0.358 | 0.393 | 0.211 | 0.437 | 0.526 | 0.218 | 0.0478 | 0.290 | 0.334 | 0.360 | 0.0844 | 0.364 | 0.233 | 0.211 | 0.00890 |

Dep. var.: log average price for electricity supply. Robust p-values in parenthesis. Variable definitions: see Table 3.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

**Table 7**
Between regression models including energy source indicators.
Source: Authors' calculations using IEA and Eurostat data.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Share of nuclear energy source > 10% | −0.290** | | | |
| | (0.036) | | | |
| Share of nuclear energy source > 20% | | −0.271* | | |
| | | (0.088) | | |
| Share of hydroelectric energy source > 20% | | | 0.044 | |
| | | | (0.760) | |
| Share of hydroelectric energy source > 30% | | | | 0.038 |
| | | | | (0.797) |
| *ERpo* | −0.126*** | −0.090** | −0.089* | −0.086* |
| | (0.005) | (0.025) | (0.053) | (0.058) |
| *ERen* | 0.044 | 0.073 | 0.037 | 0.038 |
| | (0.651) | (0.487) | (0.771) | (0.771) |
| *ERvi* | 0.015 | 0.036 | 0.030 | 0.033 |
| | (0.830) | (0.638) | (0.740) | (0.733) |
| Constant | −1.882*** | −2.270*** | −2.222*** | −2.233*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 236 | 236 | 236 | 236 |
| R-squared | 0.588 | 0.519 | 0.354 | 0.352 |
| Number of country | 15 | 15 | 15 | 15 |

Notes: The list of countries with share of nuclear energy source >10% includes Belgium, Germany, Spain, France, UK, Finland and Sweden. The list of countries with share of nuclear energy source >20% includes Belgium, France, and Sweden. The list of countries with share of hydroelectric energy source >20% includes Greece, Italy, Spain, France, Luxembourg, Portugal, Austria and Sweden. The list of countries with share of hydroelectric energy source >30% includes Spain, Luxembourg, Portugal, Austria and Sweden.
Variable definitions: see Table 3.
p-values in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.eneco.2013.05.005.

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