Economic Integration and the Markups of European Electricity Firms

Ziga Zarnic*
Katholieke Universiteit Leuven and LICOS

March 22, 2009

(The first version May 16, 2008)

Abstract

This paper uses EU firm-level panel data to estimate the impact of energy reforms on the markups of European electricity firms. Empirical results reveal that reforms have gradually reduced the markups, which is consistent with the internal market principle that competition would develop as a result of the economic integration. But the existing markup premium of incumbent firms is on average larger than theoretical models would predict under effective economic integration. Considering the heterogeneity along the firms' allocation of assets and scale economies, we find that better market access and cross-border arbitrage discipline the markups, but do not lead to competitive market outcomes due to prevailing market concentration and insufficient unbundling of transmission and distribution channels.

JEL no. F10, L11, L51, L94
Keywords: Energy market reforms; competition; firm data; price-cost margins; regulation

*Remark: I am thankful to Werner Roeger for his suggestions and discussion of the methodology used in this paper and Hylke Vandenbussche for her constructive comments. I also thank Jo Van Biesebroeck, Joep Konings, Jo Swinnen, Aida Caldera and Ilke Van Beveren for valuable discussions and comments given at different stages of the paper. A special thanks goes to the staff of CORE Department of Mahematical Engineering for providing insights into the functioning of European electricity sector. This paper has benefited from the ETSG conference in Warsaw and seminars at LICOS - KU Leuven, UC Louvain and Center for Operations Research and Econometrics. The financial support by LICOS, Katholieke Universiteit Leuven is gratefully acknowledged.
Please address correspondence to Ziga Zarnic, LICOS - KU Leuven, Deberiotstraat 34, 3000 Leuven, Belgium; E-mail: ziga.zarnic@econ.kuleuven.be

1 Introduction

The competitiveness of the electricity sector is high on the EU agenda aimed at providing competitive, but reliable and safe supply of electricity (EC 2008). The restructuring of European electricity sector is meant to integrate the national electricity systems into a single European electricity market to mitigate the market power of incumbent firms (e.g. Smeers 1997, 2005). The electricity sector is the key non-manufacturing utility sector and its competitiveness largely determines the competitiveness of other services and manufacturing sectors, because the existence of market power in this sector is easily leveraged into downstream sectors, as motivated by Arnold et al. (2006, 2008). Providing systematic evidence on the responsiveness of electricity firms' markups towards regulatory changes has thus important implications for an accurate assessment of the effectiveness of reforms.

This paper estimates the impact of European energy reforms on the price-cost margins of electricity firms. In line with the internal market principle we expect that competition would develop as a result of the economic integration, which would be reflected by lower markups.

The underlying economic mechanism is guided by the previous theoretical literature in support of our econometric analysis (in particular, Laffont and Tirole 1993, Wolak 1994, Borenstein et al. 2002). In the neoclassical profit-maximization models firms charge high prices to obtain high markups, but economic integration facilitates pro-competitive effects reflected by lower markups. Also the agency asymmetric pricing models suggest that deregulation gives incentives for markup adjustments to the level of competitive rivals. In a simple theoretical model following Bushnell et al. (2008), we demonstrate that restructuring towards greater integration leads to more competitive outcomes. In particular, a decline in the average markup is linked to increased competition from restructured electricity systems that facilitates trading activity to arbitrage between different markets.

The econometric model builds upon the Roeger (1995) approach, which main advantage is that it does not suffer from endogeneity issues when estimating firm-specific markups. We construct carefully the measures of regulatory changes to consider complementarity and sequencing of reforms, as suggested by Dewatripont and Roland (1992, 1995). Our empirical analysis confirms the theoretical predictions above as we find that reforms have gradually reduced the markups.

A further decomposition of the markup change shows that better market access and cross-border arbitrage lead to lower markups, while greater market concentration and bundling of transmission and distribution channels have the opposite effect. Overall, the existing markup premium is on average found to be larger than theoretical models would predict under effective economic integration. These results are consistent with the studies by Wolfram (1999), Jamasb and Pollitt (2005) and Roeller et al. (2007), which argue that imperfectly competitive outcomes are largely due to insufficient unbundling, rigid financial contracts and limited cross-border arbitrage of electricity constrained by poor investments into the interconnection grid. Our results are robust to alternative specifications and controlled for the firm-specific attributes inherent to the electricity sector.

The characteristics of the electricity sector makes it a rather specific utility sector because of its attributes that allow firms to exercise market power even at relatively low levels of market concentration (Smeers 2005). As emphasized in the previous work (in particular, Joskow 1997, Joskow 2003, Jamasb and Politt 2005, Wolak 2006 and Roeller et al. 2007), the market for electricity is typically regionally fragmented with rather inelastic demand elasticity as electricity consumption relies on a potentially congested transmission network. Companies with very small market shares can sometimes exert substantial market power in periods of high demand when generation capacity is tight and their output is required to satisfy demand (Borenstein et al. 2002, Smeers 2005, Bushnell et al. 2008). The electricity has been considered as a rather homogeneous product for which high fixed costs deter the entry of potential competitors. Joskow (1997) argues that production of electricity used to rely intensively on public or private monopoly suppliers, whose strategic behavior has been regulated by governments. On the one hand, the cost-inefficient storage of electricity, the limited interconnection capacities and availability of technology have favored large and vertically integrated generation facilities owned by a small number of firms. On the other hand, the institutional barriers have hampered competitive gains that could emerge from unbundled products among which consumers could switch easily.[1] The lack of competition has allowed firms to price discriminate among consumers and charge high markups by owing the supply chain from generation to distribution of electricity.

Having said that, we also provide insights into firm heterogeneity. Our results are in line with the above literature. In particular, we find that specialized firms active only in the electricity sector exhibit about 4 percentage points higher markups than the multi-product firms active also in other manufacturing and services sectors. The majority of firms are small and medium enterprises, which are more responsive to reforms than large firms. In particular, the firms with multiple subsidiaries and vertically integrated firms exhibit much higher markups than the rest. Finally, private and foreign-owned firms appear to have lower markups in concentrated markets where barriers of entry are high.

The previous literature presented above motivates largely the choice of our econometric model and the variables used in the analysis. Section 2 describes in more detail European electricity firms and regulation of the electricity systems. Section 3 presents a theoretical framework that guides the empirical analysis. Section 4 develops the empirical strategy to estimate the price-cost margins of firms and their casual relationship with the regulatory changes. Section 5 presents the main results and discusses the robustness checks. Section 6 concludes.

2 European Electricity Firms and Market Regulation

In this section, we provide a selective overview of the European electricity markets and focus on those elements that motivate our econometric model. We begin with a discussion of the existing regulation and identify the measures of institutional reforms. We next discuss the regulatory and economic factors influencing the concentration and markups of firms. Finally, we provide descriptive statistics of the firm-level dataset, documenting discussion points and introducing our econometric analysis.

[1] The environemnt has been evolving and development of new technologies does not exclusively favor large generation utilities in order to gain from economies of scale and scope. Moreover, electricity is becoming increasingly differentiated product in terms of ecological compliances, reliability and safety of supply (EC 2007, Roeller et al. 2007).

2.1 The Electricity Market and Institutional Reforms

Electricity markets are subject to extensive regulation in European countries. A certain degree of regulation is required to secure reliable and safe supply of electricity, but currently there is no single European market for electricity and regulation varies across countries. In the mid-nineties, the European Commission initiated stepwise directives to enhance the dynamic and competitive performance of a single European market. The institutional reforms have built upon the national legislations and invoked several aspects of market design and regulation evolving particularly around the market power and concentration, cross-border trade and reliability of supply (EC 2001, EC 2007a, EC 2007b). In Figures 1 to 3, we show duration of the EC Electricity Directives and systematically overview the main building steps of national legislations. These figures consider the implementation dates of key regulatory measures, in particular, they refer to operative national legislation, wholesale and retail markets.[2]

[Insert Figures 1 to 3]

The horizontal bars in Figure 1 refer to duration of national legislations and the vertical lines depict the initiation dates of the EC Electricity Directives. In most EU15 countries, a *de facto* operating authority has begun to operate soon after the establishment of national legal basis, which refers to *de jure* implementation of the national Electricity Act. In particular, Figure 1 shows that the centralized approach to market liberalization through the EC Electricity Directives has maintained the pace of reforms in the EU15 countries. In particular, the EC efforts to move towards a single electricity market have regarded sector restructuring, where the focus has increasingly been on the access to transmission and distribution networks, and competition in wholesale markets and retail supply (Jamasb and Politt 2005). Figures 2 and 3 provide cross-country information on functioning of the wholesale and retail markets. The horizontal bars in Figure 2 depict operation of the organized market exchange in each country from the establishment year. Similarly Figure 3 presents the timing of retail market opening referring to the period during which consumers were able to switch between different suppliers of electricity. Figures above show that institutional reforms vary across EU15 countries, which motivates our econometric analysis to exploit the variation in staging and vintage of institutional changes and capture their effect on price-cost margins of firms.

There is large regional fragmentation with several electricity systems in the EU, which are the UK-Ireland, Scandinavian Nord Pool, Baltic, East European, West and Southeast European, Spanish, and Italian zonal markets (Roeller et al. 2007). Figures 4 to 7 depict the evolution of different market indicators of regulatory changes across these markets.

[Insert Figures 4 to 7]

The plotted lines in Figures 4 to 6 represent the mean value of each indicator with the vertical bar denoting the variance across these markets. These markets vary largely in strictness of entry barriers, vertical integration and state ownership. This evidence is in line with Roeller et al. (2007) and ERGEG (2007 and 2008), which also document large variation in degrees

[2] Data Appendix describes in more detail the data used for construction of measures of institutional changes.

of internal competition and note that the Nordic market is the most advanced in terms of effective international integration, while the Iberian and Italian markets are particularly lagging behind. Moreover, they emphasize the importance of west European market (including France, Germany, Switzerland, Netherlands and Belgium), which is the largest regional market and its position implies that further progress toward an integrated electricity market in the EU will be dependent on the development of this market. Figures 4-6 show that the entry barriers, share of vertical integration and state ownership are gradually declining over time and moreover, the variance across countries is declining as well. Figure 7 shows that the market share of the largest electricity firm is declining at lower pace over time and remains considerably large in most of the countries. This evidence motivates our econometric analysis, where we expect that price-cost margins will be positively affected by market concentration, but could have gradually declined over time due to increased competition fostered by weaker regulatory constraints.

2.2 Preliminary Evidence on European Electricity Firms

The firm-level data are derived from a commercial database Amadeus (2008), collected by the consultancy Bureau van Dijk. The database consists of company accounts reported to national statistical offices for European companies. The advantage of using the company-accounts data is that prices generally determined by state regulators are based on accounting costs of services at the firm level (Fabrizio et al. 2007).[3] In Table 1 we present the summary statistics of the variables retrieved from the company accounts. Data Appendix describes the definitions and measurement issues of the variables we use.

[Insert Table 1]

The sample contains virtually the entire population of medium and large units of firms in the electricity sectors of ten European countries over the period 1995-2007. In particular, the firm-level data on average account for about 95% of the total employment as compared to the aggregated data retrieved from Eurostat (2008). The descriptive statistics in Table 1 are divided in three sub-samples with the last two columns referring to the period before and after the second EC Electricity Directive. The full sample includes the unbalanced data on about 700 firms with rather high capital intensity and market power of 0.42, as measured by the Lerner index bounded between 0 and 1 with lower values representing higher degrees of competition.

Two key observations emerge from the comparison of two sub-samples reported in the last two columns of Table 1. First, the firms have on average exhibited lower price-cost margins of 4 percentage points during the second EC Electricity Directive as compared to the period before 2003. Second, we note that the firms have on average employed much less capital per employee at slightly lower levels of employment and similar levels of factor costs during the period of the second EC Electricity Directive. Moreover, they exhibited higher returns on total assets after

[3] We use long-term annual data, which is motivated by the availability of comparable data across countries and by the recent literature. Smeers (2005) points out that the relevant marginal cost is the long run marginal cost that is equal to the short run marginal cost when the generation system is optimally dimensioned. However, considering long-run marginal costs has the advantage that it smoothens the trajectory of short-run variations in capacities where prices are not sufficient to justify new investments (Smeers 2005).

2003, which could imply that restructuring have lead to more efficient use of capital at slightly lower levels of employment.

The preliminary evidence above motivates further our analysis by implying downward pressure of European liberalization efforts on the price-cost margins of electricity firms. Moreover, the effect may have been heterogeneous across firms that could have been on the one hand less flexible in adjustments of their staff due to labor market rigidities, but could on the other hand adjust easier a fraction of their capital to current demand shocks. In what follows, we will look more formally for the causality between the decline in the EU price-cost margins and restructuring. The choice of variables in the econometric section is motivated by this preliminary evidence. We will explicitly consider national and firm-specific measures of regulatory changes and try to account adequately for electricity firms' attributes such as size, capital intensity, ownership and vertical integration of their activities. The ultimate objective of the next sections is to investigate whether the gradual implementation of reforms disciplined the market power of firms in European electricity sector.

3 Theoretical Framework

The recent theoretical literature assessing the market power of electricity firms typically refers to structural equilibrium models, which are discussed in more detail by Smeers (2005). In principle, an equilibrium unit commitment model decomposes a period of time into smaller segments at which the output and market price are assumed to be fixed (Smeers 2005).[4] Consumers $h \in \{1, ..., H\}$ have inverted demand function $p_t(d_{ht})$ at each period of time and firms $i \in \{1, ..., N\}$ maximize their profits by choosing the operation level of each running unit to satisfy the demand of consumers at minimal cost $C_{it}(q_{it}) = K_{it} + c_{it}q_{it}$, which may include both start-up capacity costs (K_{it}) and operational variable costs ($c_{it}q_{it}$). In the equilibrium model, demand and supply instantaneously meet at every period of time t, so that $\sum_{i=1}^{N} q_{it} = \sum_{h=1}^{H} d_{ht}$.

The unit commitment model has been among others used by Joskow and Kahn (2002) and Borenstein et al. (2002), in which marginal costs of electricity generation are simulated for different periods of time and compared to the observed prices in these periods. Bushnell et al. (2008) additionally apply a counterfactual approach to compare the perfectly competitive outcomes with the outcomes of Cournot type of competition. In this model, firms exercise market power, if the simulated price under Cournot competition exceeds the perfectly competitive price.[5]

We follow directly Bushnell et al. (2008) to provide economic intuition about the link between integration and the markups of firms. The model demonstrates that economic integration in terms of greater integration of wholesale and retail markets imposes downward pressure on the markups of incumbent firms that are simultaneously exposed to external competition, for example, from the electricity supplied through the cross-border imports or by smaller units operating only at certain periods of time (see Borenstein et al. 2002). The model by Bushnell

[4] The backbone of the equilibrium unit commitment models is the optimal dispatch model, which has been developed by the electrical engineers to solve short-run optimizations of the generation systems to satisfy an exogenously given demand, as discussed in more detail by Smeers (2005).

[5] This framework has been further extended to include other attributes of the electricity sector, such as electricity transmission and price discrimination between different types of consumers as discussed by Smeers (2005).

et al. (2008) is an elegant version of the equilibrium unit commitment model, which considers Cournot competition at the wholesale and retail levels. Firms thus maximize profits by using production quantities as the strategic decision variable. The total production of firm i at time t is represented by q_{it} and the retail sales are denoted by q^r_{it}. Following Bushnell et al. (2008), each strategic firm i at independent period of time t maximizes its profits:

$$\pi_{it}(q_{it}, q^r_{it}) = p_t(q_{it}, q_{(N-1)t})[q_{it} - q^r_{it}] + p^r_t(q^r_{it}, q^r_{(N-1)t})q^r_{it} - c_{it}q_{it} - K_{it} \tag{1}$$

where $q_{(N-i)t}$ and $q^r_{(N-i)t}$ are the quantity produced and retail quantity supplied by the other $(N-i)$ firms in Eq. (1) and p_t and p^r_t are the wholesale and retail market prices, respectively. In general, the equilibrium positions of firms consider both wholesale and retail demand elasticities as well as production capacity (K_{it}) and marginal costs (c_{it}). However, in the unit commitment model both retail quantity and prices are fixed at each unit or segment of time t. Under these assumptions, Bushnell et al. (2008) develop the Cournot equilibrium as the set of quantities that simultaneously satisfy the first order conditions for each firm i at time t as:

$$\frac{\partial \pi_{it}}{\partial q_{it}} = [p_t(q_{it}, q_{(N-i)t}) - c_{it}(q_{it}) - r_{it}(q_{it})] \geq [q^r_{it} - q_{it}]\frac{\partial p_t}{\partial q_{it}} \tag{2}$$

Equation (2) shows that the retail position of firm i matters for the level of its markup. As the retail supply increases towards the quantity produced, the marginal revenue approaches the wholesale price. This implies that the Cournot model with greater economic integration of wholesale and retail markets leads to the markups, which are closer to a competitive outcome, where the market price equals marginal revenues of the firm (see Bushnell et al. 2008). The difficulty of these models arises from identification of the marginal cost curve in the market. Within a certain period, different units of firms may operate at different segments of marginal cost curve, depending on the overall utilization of capacity in the market.[6] In general, the marginal costs of firm i can be defined as:

$$p_t(q_{it}, q_{(N-i)t}) - c_{it}(q_{it}) - r_{it}(q_{it}) \geq 0 \tag{3}$$

where the pure markup premium $(p_t - c_{it})$ should exclude the rent of capacity utilization $r_{it}(q_{it})$ to assure the investment incentives of firms in terms of scarcity rents of capacity K_{it}, as pointed out by Smeers (2005).[7] The wholesale market price is determined from the firms' residual demand function (Q_{it}), which equals the market demand (Q^m_t) net of supply from imports $\sum_{j=1}^{M} q_{jt}(p_t)$ and the fraction $\sum_{f=1}^{F} q_{ft}(p_t)$ of small units $f \in \{1, ..., F\}$ that supply electricity only at the peak levels of demand. Bushnell et al. (2008) model the additional supply as a function

[6] For example, the hydro-plants may operate exclusively at the peak-loads in certain periods of time, when demand for electricity exceeds the capacity of other sources of electricity, while the nuclear plant must operate permanently due to technical requirements. The short-term demand is rather inelastic and companies with very small market shares can sometimes exert substantial market power in periods of high demand when generation capacity is tight and their output is required to satisfy demand (Borenstein et al. 2002, Smeers 2005).

[7] Smeers (2005) discusses different extensions of equilibrium models to account for the investment decision function of firms to invest in their capacities. Firms invest in new capacities, if they can sell their output forward over the long run. In principle, this model under certain assumptions comes close to Bushnell et al. (2008) in predicting that a forward commitment towards the greater amount produced leads to more competitive outcomes as the marginal revenue approaches the wholesale price.

of price, thereby providing price responsiveness to Q_{it} as:

$$Q_{it}(p_t) = Q_t^m - \sum_{j=1}^{M} q_{jt}(p_t) - \sum_{f=1}^{F} q_{ft}(p_t) \tag{4}$$

The simple model above demonstrates that restructuring towards greater integration leads to more competitive outcomes. Moreover, a decline in the average markup is linked to increased competition from restructured electricity systems, which facilitates trading activity to arbitrage between different markets.

In what follows, we look for a testable econometric model to estimate the response of electricity firms' markups to reforms aimed at integrated European electricity market. The marginal costs are very difficult to measure directly in the data as pointed out in the previous literature. Smeers (2005) notes that the relevant cost is the long-run marginal cost, which is equal to the short-run marginal cost only when the electricity system is optimally dimensioned and prices are sufficient to justify new investments. By contrast, comparing prices with short-run variable costs may lead to upward biased estimates of markups, reflecting the short-run excessive market power in situations of tight capacities. Borenstein et al. (2008) use unique US data, which allows them to explicitly model marginal cost curve for a certain fraction of electricity units, but for the rest of them they find it impractical due to data limitations. We take into account the concerns of both views in the literature and in the following sub-sections formulate testable econometric model that allows us to directly estimate the average long-term markup for a representative sample of European electricity firms.

4 Empirical Methodology

4.1 The Baseline Model with Variable Returns to Scale

We use the Roeger (1995) approach adjusted to variable returns to scale to specify our baseline econometric model. The main intuition of this method is that the markup term is embodied in the measurement of the total factor productivity (TFP) growth, which is the output growth not accounted for by the growth in inputs. Roeger (1995) exploits the earlier empirical findings (e.g. Abbot et al. 1989) that productivity measure can be estimated either as the residual in the production function or as the residual of the dual cost function. In fact, Roeger (1995) argues that the dual Solow residual capturing output and production factor prices nests the same productivity term that will cancel out, if the dual Solow residual is deducted from the primal Solow residual.[8] We hereby outline the baseline model, while the necessary derivation steps are explained in Appendix.

Consider a log-linear homogeneous production function $Q_{it} = G(K_{it}, L_{it}, M_{it})E_{it}$ for output Q_{it}, where K_{it}, L_{it}, and M_{it} are capital, labor and material inputs (I_{it}) and E_{it} is a shift variable representing changes in productivity efficiency of a firm i at time t. That is, total factor productivity (TFP) is a residual between actual and potential output and this consideration is standard in literature (e.g. Hall 1988, Harrison 1994, Olley and Pakes 1996, Fabrizio et al. 07).

[8] Such approach for deriving of the markups under imperfect competition has been further followed by, among others, Martins et al. (1996), Konings and Vandenbussche (2005), and Vandenbussche and Zarnic (2008).

Roger (1995) circumvents the potential problem coming from the correlation of inputs with the output by subtracting the price-based from the output-based Solow residual. Decomposition of the markup and the technology component from the output-based Solow residual SR_{it} and price-based Solow residual SRP_{it} is a crucial step in the Roeger method and are expressed as:

$$SR_{it} = \mu_{it}(\Delta q_{it} - \Delta k_{it}) + (\xi_{it} - \mu_{it})e_{it} \tag{5}$$

$$SRP_{it} = \mu_{it}(\Delta F_{Kit} - \Delta p_{it}) + (\xi_{it} - \mu_{it})e_{it} \tag{6}$$

where the right-hand side is decomposed in the markup and the pure technology component, where Lerner index for a firm i at time t is denoted by $\mu_{it} = \frac{P_{it}-c_{it}}{P_{it}}$, scale economies are denoted by ξ_{it} and small letters refer to the logarithms.[9] Similar to Fabrizio et al. (2007), we hereby implicitly assume that production factors are to a certain degree substitutable only in the long-run, but fixed in the medium-run.[10]

The output-based and price-based residuals are respectively the differences between the growth rates of output Δq_{it} and weigthed inputs $\alpha_{Iit}\Delta I_{it}$, and alternatively the differences between the growth rates of output prices Δp_{it} and weigthed input prices $\alpha_{Iit}\Delta F_{Iit}$. More formally, the Solow residuals can be expressed as:

$$SR_{it} = \Delta q_{it} - \sum_I \alpha_{Iit}\Delta I_{it} \tag{7}$$

$$SRP_{it} = \sum_I \alpha_{Iit}\Delta F_{Iit} - \Delta p_{it} \tag{8}$$

where the share of inputs (I_{it}) in total revenues ($P_{it}Q_{it}$) are denoted by $\alpha_{Iit} = \frac{F_{Iit}I_{it}}{P_{it}Q_{it}}$ with the letters F and P representing input and output prices. To obtain a price-cost margin term $\mu_{it} = \frac{P_{it}-c_{it}}{c_{it}}$, which can be directly estimated, one has to subtract the price-based residual SRP_{it} from the output-based residual SR_{it} as:

$$(\triangle q_{it} + \triangle p_{it}) - \sum_I \alpha_{Iit}\Delta F_{Iit} = \mu_{it}[(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle F_{Kit})] \tag{9}$$

The price-cost margin term (μ_{it}) in (9) can be estimated consistently, because the error term capturing unobserved productivity shocks has canceled out. The baseline econometric model is thus simply specified as:

$$\Delta y_{it} = a_i + \mu_1 \Delta x_{it} + \varepsilon_{it} \tag{10}$$

where the left-hand side variable ($\triangle Y_{it}$) represents the difference between the Solow residuals and the right-hand side explanatory variable ($\triangle X_{it}$) represents the growth rate of output per value of capital with the white noise error term ε_{it} for firm i at time t.

[9] Roeger (1995) shows that the change in the marginal cost ($\triangle c_{it}$) is a weighted average of the changes in input prices (F_{Iit}) with respect to their relative cost shares in the firm's cost function (ϕ_{Iit}), accounting for the change in technology (e_{it}), i.e. $\triangle c_{it} = \phi_{Iit}\triangle F_{Iit} - \triangle e_{it}$.

[10] This assumption is relaxed in the next sub-section, in which we consider that firms can adjust a fraction of their capital to current demand shocks.

4.2 Firms' Allocation of Capital Assets

We now consider that due to restructuring the firms can adjust a fraction of their capital assets to current demand shocks by following the approach by Roeger and Warzynski (2004). While firms may be less flexible in adjustments of labor force, e.g. due to European labor market rigidities, they can adjust a fraction of capital to current demand shocks. In other words, this extension allows us to come closer to the estimate of pure markup premium, which is controlled for the part of scarcity rent of capacity utilization r_{it} in (2) providing incentives for future investments.

Consider a log-linear homogeneous production function $Q^s_{it} = \min(\alpha_{Lit}L_{it}, \alpha_{Kit}K^v_{it}) - K^f_{it}$ with the variable capital input $K^v_{it} = s_{it}K_{it}$ where s_{it} measures the degree of variable capital within the capital stock K_{it}. Similar to Roeger (1995) with the share of inputs in revenues, consider now the share of inputs in total costs. The output and price-based Solow residuals are defined as:

$$SR^s_{it} = \triangle q_{it} - (\alpha^s_{Kit} \triangle k_{it} + \alpha^s_{Lit} \triangle l_{it} + \alpha^s_{Mit} \triangle m_{it}) + \triangle e_{it} \tag{11}$$

$$SRP^s_{it} = \alpha^s_{Kit} \triangle F_{Kit} + \alpha^s_{Lit} \triangle F_{Lit} + \alpha^s_{Mit} \triangle F_{Mit} - \triangle p_{it} - \triangle e_{it} \tag{12}$$

where the shares of input costs in total costs, $C_{it} = F_{Iit}I_{it}$, are denoted by $\alpha^s_{Kit} = \frac{F_{Kit}K_{it}}{F_{Iit}I_{it}}$, $\alpha^s_{Lit} = \frac{F_{Lit}L_{it}}{F_{Iit}I_{it}}$ and $\alpha^s_{Mit} = \frac{F_{Mit}M_{it}}{F_{Iit}I_{it}}$ with the letter F_{it} denoting input prices and I_{it} total inputs. The variable capital is not directly observed in the data, so Roeger and Warzynski (2004) suggest to express its growth rate in terms of revealed productivity growth, Δx_{it}, and observable capital input, Δk_{it}. The growth rate of variable capital input is then defined as:

$$\Delta k^v_{it} = \varepsilon_{sx}\Delta x_{it} + \Delta k_{it} \tag{13}$$

Consider the output-based and price-based Solow residuals in (11) and (12), which are adjusted for the share of inputs in the total costs, and subtract them to obtain the following expression:

$$(\triangle q_{it} + \triangle p_{it}) - \alpha^s_{Iit}\Omega^s_{Iit} = (1 - s_{it})\alpha^s_{Kit}[(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle F_{Kit})] + s_{it}\alpha^s_{Kit}\varepsilon_{sx} \triangle x_{it} \tag{14}$$

where $\alpha^s_{Iit}\Omega^s_{Iit} = \alpha^s_{Kit}(\triangle k_{it} + \triangle F_{Kit}) + \alpha^s_{Lit}(\triangle l_{it} + \triangle F_{Lit}) + \alpha^s_{Mit}(\triangle m_{it} + \triangle F_{Mit})$. The left-hand side variable represents the subtraction of Solow residuals the right-hand side represents the growth rate in revenues per capital weighted by the share of capital in total costs considering productivity of a firm i at time t. The testable model of the price-cost margins (μ_{it}) corrected for the variable capital is estimated with a system of seemingly unrelated equations, referring to (10) and (14):

$$\begin{cases} \Delta y_{it} = a_i + \mu_1 \Delta x_{it} + \varepsilon_{it} \\ \Delta y^s_{it} = a_i + \sigma_1 \Delta x^s_{it} + \varepsilon_{it} \end{cases} \tag{15}$$

where the share of variable capital σ_1 is estimated as a nonlinear logistic function, described in more detail in Appendix. In this model, the price-cost margin is explicitly controlled for the variable part of capital of firm i at time t.

5 Econometric Results

To test whether the price-cost margins were affected by the institutional changes leading to fiercer competition, we first look at the price-cost margins and establish their link with main determinants of competitive pressure. As motivated by the previous literature at the beginning of this paper, we estimate the markup changes associated with cross-border arbitrage and market concentration.[11] We next investigate the effect of the second EC Electricity Directive from 2003. This exercise is motivated by the official EC document suggesting that further liberalization of European electricity markets through the second EC Directive would facilitate pro-competitive effects (EC 2007). We further define carefully the counterfactual measures of regulatory changes to verify that the price-cost margins have not declined after the second EC Electricity Directive due to a common electricity sector effect prevalent in all European countries. We conclude by discussing the heterogeneous responses of firms towards energy reforms.

5.1 Evidence on Markups

5.1.1 Cross-Border Trade Arbitrage and Market Concentration

In our baseline specification, we use Eq. (10) in a log-linear fixed-effects model by applying annual fixed effects to control for any changes in markups that are common across firms.[12] We further make the standard assumption that is done in all applications of this type (see e.g. Levinsohn 1993, Konings et al. 2005, Van Biesebroeck 2007), that the markups are invariant within the same sector or group of firms that we consider. It is not possible to estimate a markup for each firm individually, because we would not have enough degrees of freedom. To assess the effect of trade and market concentration on firms' price-cost margins, we interact Δx_{it} with the electricity sector (j) trade arbitrage, T_{jt}, and market concentration, H_{jt}, at time t.[13] The baseline regression model is then specified as:

$$\Delta y_{it} = a_i + \mu_1 \Delta x_{it} + \beta_1 \Delta x_{it} \times T_{jt} + \beta_2 \Delta x_{it} \times H_{jt} + \beta_3 M_{jt} + \beta_4 H_{jt} + \beta_5 gdp_{jt} + \beta_4 D_t + \varepsilon_{it} \quad (20)$$

where the dependent variable (Δy_{it}) represents the subtraction of Solow residuals and the parameter of our main interest is the average price-cost margin captured by the estimation coefficient μ_1. The coefficients β_1 and β_2 indicate the change in price-cost margin associated with trade arbitrage (T_{jt}) and market concentration (H_{jt}). In all our models with interaction effects we always include the main effects of the variables (referring to β_3 and β_4) that were used to compute the interaction terms to exclude the possibility that main effects and interaction effects are confounded. A set of controls such as gdp_{jt} and year dummies D_t control for business

[11] For example, Domowitz et al. (1988) were among the first to provide empirical evidence that concentration is positively related to price-cost margins. Konings et al. (2005) and Vandenbussche and Zarnic (2008) among others show that markups may be negatively affected by import competition.

[12] Following the results of the Hausman test we prefer a fixed-effects model over a random-effects model. The F-test indicated that fixed effects were significant in all model specifications. We control for business cycles with the real GDP growth rates to proxy for country-level shifts of demand as in Vandenbussche and Zarnic (2008). The Appendix describes the data and variables in more detail.

[13] We measure trade arbitrage as imports over imports and sales of electricity output of country k at time t, similar to Vandenbussche and Zarnic (2008). Market concentration is proxied by Herfindahl index as the sum of the squares of the market shares of each individual firm computed at the 3-digit electricity sector for country-year pairs.

cycles and macro effects common across firms over time. Finally, a_i stands for an unobservable firm-level fixed effect, which may capture unobserved sunk costs, quality of the managers, and other fixed factors we may not observe (as in Konings et al. 2005).

[Insert Table 2]

The first column (1) of Table 2 reports the estimation results of our baseline model specified by (10). We see that the average price-cost margin is estimated at almost 45%. We roughly compare this point estimate to the recent evidence by the EC (2007). Their report documents a large variation in terms of price-cost margins across six European countries, ranging from 31% for the UK to 51% for Germany during 2003-2005. In contrast to their study, we do not have comparable data for the UK but we include a larger sample of ten countries for a longer period of 1995-2007, as described in Data Appendix. The level of price-cost margin is relatively high, which confirms the view of Smeers (2005) that the level of competition in the European electricity sectors remains unsatisfactory as the integration of national electricity systems into a single internal European electricity market is not progressing well.

As expected in line with previous sections, we find that the price-cost margins are positively associated with market concentration and negatively with the trade arbitrage.[14] On the one hand, highly concentrated sectors reflect less competitive pressure, which allows firms to exert a certain degree of their monopoly power reflected in higher price-cost margins. The coefficient 0.45 in column (1) of Table 2 suggests that an increase in market concentration of 10 percentage points is equivalent to an increase in the average price-cost margin of 4.5 percentage points. This suggests that existing institutional reforms insufficiently increase the number of competing firms, as suggested by Smeers (2005).[15] On the other hand, trade arbitrage is shown to be still rather limited and has to a lesser degree contributed to a decline in price-cost margins. The negative coefficient -0.25 in column (1) suggests that an increase in trade arbitrage of 10 percentage points is equivalent to a decline in the average price-cost margin of 2.5 percentage points.

Note that these results are robust with respect to potential variables returns to scale. In the empirical analysis using Eq. (10), we first compute the average returns of scale ξ_{it} at the 3-digit electricity industry level from the production function $Q_{it} = E_{it}K_{it}^{\alpha}L_{it}^{\beta}M_{it}^{\gamma}$ to compute the weighted shares of input costs, $\sum_{I} \alpha_{Iit}\Delta F_{Iit}$, in Eq. (9)[16]:

[14] The average Herfindahl index (HHI) calculated with our data is on average rather low at 15% and has gradually dropped from 43% in 1995 to 12% in 2007. As discussed by Smeers (2005), in restructured electricity markets even companies with very small market share can exert significant market power. Import penetration is on average around 68% with the large variation across our sample of countries, ranging from 2% for Norway and 98% for Luxembourg, which in contrast to Norway imports most of its electricity from neighboring countries.

[15] Smeers (2005) states that the evaluation of institutional measures partly relies on computable oligopoly models of the restructured electricity sector. He analyses the recent literature and concludes that these models currently cannot provide unambiguous results and thus are not yet capable of providing the degree of legal and regulatory certainty that the importance of the ex ante institutional measures requires.

[16] At this point of our analysis, we are interested in the average markups across all electricity firms and thus consider the estimate of average returns to scale for the 3-digit electricity sector in each year and country. On average across Eruopean countries over the last decades, there have been decreasing returns to scale of the order 0.94. In the last sub-section of results we present estimates specific to different cohorts of firms, which are adjsuted for returns to scale specific to each group of firms, as for example, we observe that scale economies vary with respect to type of firms from roughly 0.78 to 1.19 over the sample period.

$$\sum_I \alpha_{Iit} \Delta F_{Iit} = (\xi_{it} - \alpha_{Lit} - \alpha_{Mit}) \triangle F_{Kit} + \alpha_{Lit} \triangle F_{Lit} + \alpha_{Mit} \triangle F_{Mit}$$

5.1.2 Robustness Checks

To verify the robustness of the baseline model we consider a few alternative specifications common in the empirical literature to estimate the price-cost margins of firms. We describe the necessary details of these models in Appendix.

We first refer to the variable capital model that considers the firms' allocation of capital assets as defined in Section 4.2. This method provides an alternative way to estimate the price-cost margins by maintaining the hypothesis that marginal costs and marginal revenues are unobservable and thus price-cost margins are estimated using the notion of total factor productivity. It steps aside from the price-cost margin (PCM) method applied to the electricity sector among others by Joskow and Schmalensee (1983), Wolfram (1999) and Wolak (2003). This strand of literature argues that the production technology in the electricity sector is straightforward and well understood and thus marginal costs can be directly computed on the basis of the input costs and generated output. Therefore, we also present the PCM model.[17] As the third alternative, we apply a rather standard approach in the literature on productivity developed by Olley and Pakes (1996) and discussed by Van Biesebroeck (2007) to correct the price-cost margins for productivity shocks with an instrument that includes a polynomial of input costs.[18] We document in Table 2 that the estimates of price-cost margins are not sensitive with respect to any of these methods used in the analysis.

The regression models in columns (2) to (5) refer to alternative specifications defined respectively by Eq. (15) in the previous section and (D.3) and (E.5) presented in Appendix. In particular, we try to account for the part of markup related to scarcity rent utilization $r_{it}(q_{it})$ in Eq. (3). The results from the variable capital model estimated by (15) in column (2) are consistent with the theory. We see that consideration of capital asset allocation is associated with lower markups in the order of 3 percentage points. Given column (3), we find that the price-cost margins are over-estimated when considering constant returns to scale. Importantly, we find that our baseline method in (1) is highly comparable, with a difference of less than 1 percentage point, to the commonly applied price-cost margin (PCM) method in (4), which uses directly observable data to compute price-cost margins. Further, we consider the effect of market concentration and trade arbitrage in a similar way as in Eq. (10). We find that the average price-cost margins do not vary much across different specifications.[19]

[17] We consider this method is less suitable to our data, because we do not directly observe sufficient plant-level information on transformation efficiency and daily clearings of supply and demand for electricity from the spot markets. Moreover, such data are less not available for sufficiently long time span to measure the effect of institutional reforms, because their availability also depends on operation of the organized market exchanges across countries.

[18] A disadvantage of this method comes from its requirement that only the data with non-negative values of capital can be used. Moreover, the data sample suffers further truncations because only those firms are considered for which consecutive time series are available. This may lead to sample selection problems and thus we refer to this method as an alternative robustness check of the price-cost margin estimates.

[19] The estimates are somewhat higher in the last column (5) due to lower number of observations, because the Olley-Pakes specification requires certain data restrictions as described in Appendix. Using the variable capital model, we estimate that the bulk of capital is fixed (86%) for the European electricity firms during 1995-2007, which likely explains why the results on price-cost margins do not differ substantially from the results obtained

The results above imply that the price-cost margins are on average still relatively high across our sample of countries and that cross-border arbitrage is insufficient to counterbalance the positive effect of market concentration. As discussed in the previous literature (e.g. Jamasb and Pollitt 2005 and Roeller et al. 2007), this is likely due to regulatory constraints, insufficient unbundling and limited cross-border trade of electricity due to the existing interconnection grid. This motivates the analysis of the next sub-sections, where we look closely at the regulatory changes across countries to investigate their impact on the price-cost margins of electricity firms.

5.2 The Impact of Reforms on Markups

5.2.1 EC Electricity Directives

Roeger and Warzynski (2004) find that the first EC Electricity Directive in 1997 contributed to a decline in average price-cost margins for the sample of 500 largest European firms during 1995-1999. The official documents by the EC suggest that further liberalization of European electricity markets would lead to pro-competitive effects on the markups of firms (EC 2007). This motivates our next step to compare the price-cost margins between two sub-samples around the initiation of the second EC Electricity Directive in 2003. We consider a sufficient time span before and after the second EC Electricity Directive, which appeared to be stricter than the first EC Directive with respect to harmonization of national legislations and opening of wholesale and retail markets (EC 2007).

[Insert Table 3]

The regression models are constructed in the same way as in the previous sub-section. The first two columns (1) and (2) of Table 3 report the estimates of price-cost margins before and after the second EC Electricity Directive. Following the F-test, we note that the price-cost margins between both sub-samples are statistically different from each other. We find that the price-cost margins were on average lower (41%) after the EC Directive and higher (53%) before the event. A similar difference between markups of both periods in the order of 10% emerges also from the robustness checks. This suggests that the price-cost margins may have declined due to liberalization incentives.

5.2.2 Counterfactual Measures of Institutional Reforms

In this sub-section, we look for counterfactual measures of regulatory changes to verify that the price-cost margins have not declined after the second EC Electricity Directive due to a common electricity sector effect prevalent in all European countries. We use all available information from the national and external sources to construct the variables that are in line with the economic intuition discussed in the recent literature, which is presented in previous sections. The detailed descriptions of variables and sources are provided in Data Appendix.

We define the baseline model in a similar way as in the previous sub-sections, but additionally include a variable that captures the effect of the institutional reform. The regression model is specified as:

by the baseline model using the Roeger (1995) method.

$$\Delta y_{it} = a_i + \mu_1 \Delta x_{it} + \beta_1 \Delta x_{it} \times Z_{it} + \beta_2 \Delta x_{it} \times M_{jt} + \beta_3 \Delta x_{it} \times H_{jt} + D_t + \varepsilon_{it} \qquad (21)$$

The specification (21) is similar to (20), but in addition we interact the price-cost margin term with the variable measuring a specific change in regulation, denoted by $\Delta x_{it} \times Z_{it}$ for firm i at time t.[20] The parameter of our main interest here is β_1 which captures the effect of a specific institutional measure or firm attribute on the price-cost margin, which is labelled "*Effect of institutional measure*" in Table 4.

[Insert Table 4]

Each column of Table 4 refers to a different institutional measure in columns from (1) to (7) to capture the effects of legal constraints, market access and foreclosure on the markups. A *de jure* policy in column (1), measured by the number of years from the establishment of national electricity liberalization act, and *de facto* operating time of the authority (2) assigned to its implementation are expected to enhance market competitiveness reflected by lower markups. The results in (1) and (2) suggest that the longer in time the national authority operates, the lower the markups. But a rather low economic significance of these results points at inferior effectiveness of national authorities.

To give further insights about the strictness of institutional market barriers, we refer to the OECD index of regulatory burden in column (3) and find its positive relationship with the markup. Intuitively, high regulatory constraints such as entry barriers and rigid financial contracts captured by this index prevent new entry and to a certain degree condition monopoly behavior reflected by high price-cost margins.[21] Hopenhayn (1992) was among the first to show that market entry barriers matter for the markups of firms. Dunne and Roberts (2007) demonstrate the case in their analysis of US health service markets and argue that if larger markets are more competitive they exhibit lower markups, although the average firm size could be larger because the firms must sell more output to cover their fixed costs. The higher entry costs or lower market access insulate incumbent firms from the competitive pressure of entry and allows more inefficient firms to survive. Intuitively, better access to the wholesale and retail markets would foster competitive behavior by increasing the number of players on the demand and supply sides of the market. We expect that pro-competitive effect would lead to lower markups.[22]

[20] The coefficients β_2 and β_3 indicate the change in price-cost margin associated with import penetration (M_{jt}) and market concentration (H_{jt}). In all our models with interaction effects we always include the main effects of the variables that were used to compute the interaction terms to exclude the possibility that main effects and interaction effects are confounded. A set of controls such as gdp_{jt} and year dummies D_t control for business cycles and macro effects common across firms over time. Finally, a_i stands for an unobservable firm-level fixed effect.

[21] As discussed in Data Appendix, this is a composite variable that captures a set of different indicators and its economic significance should therefore be interpreted with caution.

[22] Moreover, Aw et al. (2001 and 2003) discuss that the existence of entry costs nests further implications for the market competitiveness. They use micro panel data for producers in seven two-digit manufacturing industries in South Korea and Taiwan and identify a number of systematic differences in industry structure related to entry costs. Their empirical findings indicate Taiwanese industries are characterised by less concentrated market structure, more producer turnover, smaller within-industry productivity dispersion across producers, a smaller percentage of plants operating at low productivity levels, and smaller productivity differentials between surviving and failing producers. These patterns are consistent with strong competitive pressures in Taiwan that lead to market selection based on productivity differences. The patterns in Korea are consistent with the presence of

The results in columns (4), (5), and (6) in Table 5 capture the effect of wholesale and retail market access on the price-cost margins. Consistent with the considerations above, we find that the price-cost margin is negatively associated with better functioning of wholesale and retail markets. We also find that the retail market access effect is dominantly driven by the ability of large industrial consumers to switch between electricity providers (5). We do not find any evidence of small industrial or household switching on the markups. This is in line with the recent reports that wholesale markets are not operating well in most European markets for electricity, moreover, there is little evidence of switching for household and small industrial consumers (Al-Sunaidy and Green 2006, Roeller et al. 2007, EC 2007). Given the last column (7), we find that greater market foreclosure due to vertical integration of transmission and distribution channels is significantly related to higher markups.

[Insert Table 5]

With respect to other variables in the models above, the effects of market concentration and trade arbitrage remain similar to the ones reported in Table 2. The directly comparable results from the variable capital model reported in Table 5 are close to the ones from the baseline model in Table 4, which adds to the robustness of our results.[23] The above results are consistent with the theoretical literature and imply a gradual decline in markups associated with industry restructuring. In particular, our results give support for theoretical models emphasizing the complementarity and sequencing of reforms that gradually increase competitive pressure (e.g. Dewatripont and Roland 1992, 1995). We find that greater trade arbitrage and better access to wholesale and retail markets are associated with a decline in markups, while greater market concentration and market foreclosure through bundling of transmission and distribution channels are associated with higher markups.

5.3 Firm Heterogeneity

5.3.1 Ownership Structure and Diversification of Firms

Joskow (1997) among others points out that production of electricity used to rely intensively on public or private monopoly suppliers, whose strategic behavior has been regulated by governments. The cost-inefficient storage of electricity and limited interconnection capacities have favored large and vertically integrated firms in concentrated markets. Damijan et al. (2005) and Konings et al. (2005) further suggest that privatization could lead to more competitive outcomes as the changes in ownership structure improve the performance of firms, however conditional on the prevailing market concentration. Their studies motivate the choice of our ownership variables and guide interpretation of the results. Moreover, the recent evidence by Konings and Vandenbussche (2008) suggests that firms may respond heterogeneously to policy instruments.

some impediments to exit or entry that insulate inefficient producers from market pressures

For example, once firms manage to enter they are less likely to exit, because they do not want to re-incur the high entry costs. This in turn explains why there is very little exit of around 4 percent in our sample of electricity firms, as discussed in our last robustness check on sample selection.

[23] The sample of observations in Tables 4 and 5 is kept the same as in Tables 1 and 2, if there are available sufficient comparable data that are required for the construction of institutional measures or firm attributes. For brevity reasons, we do not report results for other specifications as they are less preferred due to their sample restrictions.

In columns (1) and (2) of Table 6, we first interact the markup term from Eq. (10) with the measure of market concentration (H_{jt}) and a dummy taking value 1, if a firm bundles transmission and distribution channels and 0 otherwise. The positive coefficient of 0.38 in column (1) suggests that vertically integrated firms exhibit much higher markups, if market concentration is high. This result also holds, but it is lower, when controlling for the variable part of capital in (2). Looking at the firm ownership in columns (3) to (6) in a similar fashion as in (1) and (2), we find that the private and foreign-owned firms have lower markups if market concentration of the incumbent firms is high.[24]

In Table 7 we investigate, if the firms respond heterogeneously to regulatory changes. In line with the literature outlined in the introduction (e.g. Joskow 1997), we expect that the size of firms as well as organization of their activities could matter for their performance. Column (1) is directly comparable to Tables 2 and 3. It refers to all firms for better comparison to sub-groups of firms in columns (2) to (7). Columns (2) and (3) compare diversified multi-product firms (2) that report their activity across different sectors and specialized firms (3) that report their activity only within the electricity sector. We find that the latter exhibit higher markups by 5 percentage points. Their markups are also more responsive to energy reforms than of the multi-product firms active also in other sectors.

Roberts and Supina (1996) show that markups may vary across the size distribution of firms. In their study they use plant-level data for various homogenous US manufactured products and show that the markups decline with increases in plant size for most observations. If larger plants produce very homogeneous or standardized products like electricity then markups may vary with size. Following Bresnahan (1989), the markups can be expressed as $p_{it}/c_{it} = -(1-\lambda s_{it}/\eta)$, where s_{it} is a the firm's i market share in time t, λ is the market competitiveness index and η is the market demand elasticity. The firms with larger market shares will have larger markups. In this case anything that decreases demand elasticity or increases competitiveness will increase the markups of all firms in the market. This could contribute to a negative markup-size relationship if markets were geographically segmented as in European electricity industry and larger firms served in larger more competitive markets (see Roberts and Supina 1996). Small and medium enterprises (SME) with less than 250 employees constitute the majority of our sample, given column (4) of Table 7. Comparing columns (4) and (5) we find that large firms employing more than 250 employees appear to have smaller markups in the range of 6 percentage points. We find that these large firms are also more responsive to reforms than SME. In column (6), we find that firms with multiple subsidiaries are able to charge much higher markups than the firms with no-subsidiaries in column (7).

[Insert Table 7]

5.3.2 Electricity Generators

There are several sources of electricity and thus far we have not explicitly considered the heterogeneity of electricity producers. For example, we expect that the plants with higher fixed capital

[24] The regression results using ownership status are based on lesser observations, because we drop from the analysis those firms for which we could not trace ownership information in the Amadeus data. This ensures that the information we use is a good measure of whether a firm is private or foreign-owned.

outlays such as nuclear plants would exhibit superior markups over others. As discussed by Wolfram (1999), nuclear plants incur large fixed investment cost, but have very low marginal costs as they generate electricity continuously, except during routine maintenance, refueling outages or unexpected failures. If one or more nuclear plants are out of service for either reason, more expensive coal- or oil-fired plants must be run at every level of demand. By contrast, certain units such as hydro- or wind-plants can be switched on at short periods during peak-levels of demand. The latter units nay have high markups at those moments of tight capacities, but lower markups than nuclear firms on the annual basis. This is true, if they can not realize sufficient short-term returns to cover the long-term investment projects. Having said that, we expect that nuclear plants would exhibit the largest markups due to their inherent efficiency and less efficient coal- and oil-fired plants the lowest markups.

[Insert Table 8]

The results of Table 8 confirm the above considerations.[25] The coefficient of 0.381 in column (1) of Table 8 suggests that an increase of nuclear plants' electricity output share in total output by 10 percentage points is equivalent to an increase in the average price-cost margin of 3.81 percentage points. By contrast, an opposite relation is found for coal-fired plants in (4). The gas-fired plants in (3) exhibit somewhat larger markups (0.24) than the rest of the plants. A possible reason is that the gas-fired plants internalize part of their input costs by owning the gas-distribution channels, which gives them the edge over coal-fired plants that are mutually linked to the external suppliers of coal. We also find that the hydro-powered plants in (5) exhibit slightly lower markups (-0.06). This results suggests that even though the hydro-plants may exhibit high markups in the short-periods of time of tight capacities, they fail to gain from scale economies because they do not operate continuously. Moreover, the availability of wind-plant and renewable electricity is still rather scarce across countries and its generation process is relatively expensive due to their limited operation times. In columns (6) and (7) we report that these units exhibit lower markups than the rest of units.

These results should be seen as an exploratory effort into providing evidence on generator heterogeneity. The presence of electricity generating plants is measured by the share of their output in the total output of electricity per country. The results in Table 8 should thus be interpreted with caution due to unavailable plant-level information on electricity generation that could be matched with our firm data.[26]

5.3.3 Sample Selection

We consider some other robustness checks in Table 9 to verify the selection of our sample and validity of the results. Following Eq. (10) in columns (1) and (3) and Eq. (20) in column (2), we first check whether our results in Table 2 are influenced by using a balanced panel

[25] Number of observations vary across the columns, because in each case we consider only countries for which there exist all electricity sources under analysis. For example, nuclear electricity represents on average over years about 77 percent of total electricity in France and 56 percent in Belgium, but is not available in Austria. The levels of markups are thus not directly comparable across columns, but should be referred to the sample of countries under analysis.

[26] About one third of firms in our data report to use a mix of different electricity generators during each year fired at different points in time, among which is impossible to distinguish.

of continuing firms over the sample period. Using a balanced panel may result in a selection bias, because no allowance is made for entry and exit (see Van Biesebroeck 2007 and 2008). Comparing the results of the balanced and unbalanced sample for the fixed-effects estimator enables us to determine whether this estimator adequately corrects for the selection bias, that is, whether exit decisions at the firm level are only determined by the time-invariant firm-specific effects. Comparing the baseline results in column (1) of Table 9 with the results in column (1) of Table 2, we note a negligible difference of less than 1 percentage point between both estimates of price-cost margins. Moreover, the result appear to be robust also with respect to alternative specifications using the variable capital model in (2) and assuming constant returns to scale in column (3) of Table 9. The variables of market concentration and trade arbitrage have predicted signs and the estimates are comparable to the ones in Table 2.

[Insert Table 9]

We next consider that the price-cost margins could be influenced by the markets with fiercer internal competition. The increased competition forces less efficient firms to exit, while allowing for entry of more efficient firms (see e.g. Bernard et al. 2007). Thus we would expect that by excluding the markets with higher trade activity from our sample would lead to an increase of the average markup for the rest of the sample. In columns (4) to (6), we see that the price-cost margin are indeed somewhat higher than observed in Table 2, when excluding the Nordic Pool from our sample that encompasses Scandinavian countries with intense internal market trade.

6 Conclusion

This paper has presented a number of estimates of price-cost margins and their relationship with economic integration of European electricity systems towards a single European market. Our results are in line with the theoretical literature and imply a gradual decline in markups associated with deregulation and restructuring of the electricity sector. We find that greater openness to cross-border trade, better access to wholesale and retail markets and privatization in concentrated markets are associated with a decline in markups. By contrast, greater market concentration and bundling of transmission and distribution channels are associated with higher markups. Exploiting the variation in staging of institutional reforms across different European countries, this paper provides robust firm-level evidence of their impact on the price-cost margins of European electricity firms.

An effective economic integration of the European electricity systems would on average definitely reduce the market power of the incumbents (Smeers 2005). This would be in line with the internal market principle that competition would develop as a result of the economic integration, which would in turn reduce the markups of even the largest incumbent firms. However, we find that in spite of the EC liberalization efforts, the electricity firms on average still exhibit considerable price-cost margins of about 40 percent.

The existing market power is larger than most theoretical models would predict (Wolfram 1999, Borenstein et al. 2002, and Bushnell et al. 2008). In conclusion, our findings confirm the discussions in the previous literature about the sluggish progress of the integration process, which is mainly due to inadequate harmonization measures, insufficient unbundling and limited cross-border trade that are needed to foster competition and reduce the market power of firms (Jamasb and Pollitt 2005, Smeers 2005 and Roeller et al. 2007). Smeers (2005) further notes that the economic integration can be achieved by ex-ante policy instruments improving transmission and balancing in the European electricity system.

References

[1] Abbot, T.A., et al. (1989). Short Run Movements in Productivity: Market Power versus Capacity Utilization. Harvard University Press, Cambridge, MA.

[2] Al-Sunaidy, A., Green, R. (2006). Electricity Deregulation in OECD Countries. *Energy* 31: 769-787.

[3] Arnold, J.M., Javorcik, B.S., and A. Mattoo (2006). The Productivity Effects of Services Liberalization: Evidence from the Czech Republic. *World Bank Working Paper* WPS4109: 1-38.

[4] Arnold, J.M., Nicoletti, G. and S. Scarpetta (2008). Regulation, Allocative Efficiency and Productivity in OECD Countries: Industry and Firm-Level Evidence. OECD Economics Department Working Papers 616: 1-67.

[5] Aw, B.-J., Chen, X., and M.J. Roberts (2001). Firm-Level Evidence on Productivity Differentials and Turnover in Taiwanese Manufacturing. *Journal of Development Economics* 66(1): 51-86.

[6] Aw, B.-J., Chung, S. and M.J. Roberts (2003). Productivity, Output, and Failure: A Comparison of Taiwanese and Korean Manufacturers. *Economic Journal* 113(491): 485-510.

[7] Bernard, A.B., et al. (2007). Firms in International Trade. Journal of Economic Perspectives 21 (3): 105-130.

[8] Borenstein, S., Bushnell, J. and Wolak, F., 2002. Measuring Market Inefficiencies in California's Restructured Wholesale Electricity Market, American Economic Review, 92, 1376-1405.

[9] Borenstein, S., et al. (2008). Inefficiencies and Market Power in Financial Arbitrage: A Study of California's Electricity Markets. *Journal of Industrial Economics*, forthcoming.

[10] Bower, J. (2002). Seeking the Single European Electricity Market. *Working Paper*, Oxford Institute for Energy Studies, July 2002: 1-48.

[11] Bushnell, J.B., Mansur, E.T., and Saravia, C. (2008). Vertical Arrangements, Market Structure, and Competition: An Analysis of Restructured U.S.Electricity Markets. *American Economic Review* 98 (1): 237-266.

[12] Conway, P., Nicoletti, G. (2006). Product Market Regulation in the Non-Manufacturing Sectors of OECD Countries: Measurement and Highlights. *Economics Department Working Papers* 530: 1-64.

[13] Damijan, J.P., Majcen, M., Rojec, M. and M. Simoneti (2005). Case-by-Case Versus mass privatization in transition economies: Initial owner and final seller effects on performance of firms in Slovenia. *World Development* 33 (10): 1603-1625.

[14] Damijan, J.P and M. Knell (2005). How Important Is Trade and Foreign Ownership in Closing the Technology Gap? Evidence from Estonia and Slovenia. *Review of Wrold Economics* 141 (2): 271-295.

[15] Dunne, T., Roberts, M., Klimek, S. and D.Y. Xu (2007). The Dynamics of Market Structure and Market Size in Two Health Services Industries. *Working Papers* 07-26, Center for Economic Studies, U.S. Census Bureau: 1-35.

[16] Dewatripont, M., Roland, G. (1992). The Virtues of Gradualism and Legitimacy in the Transition to a Market Economy. *Economic Journal* 102: 291-300.

[17] Dewatripont, M., Roland, G. (1995). The Design of Reform Packages under Uncertainty. *American Economic Review* 83: 107–123.

[18] Domovitz, I., Hubbard, R.G. and Petersen, B.C. (1988). Market structure and cyclical fluctuations in US manufacturing. *Review of Economics and Statistics* 67: 55–66.

[19] European Commission (2007a). Prospects for the Internal Gas and Electricity Market: Implementation Report. *Commission Staff Working Document*, COM(2006) 841 final: 1-167.

[20] European Commission DG COMP (2007b). Structure and Performance of Six European Wholesale Electricity Markets in 2003, 2004 and 2005. *London Economics Report*, February 2007: 1-40.

[21] European Commission DG TREN (2001). Electricity Liberalization Indicators in Europe. *OXERA Proposal*, October 2001: 1-202.

[22] European Regulators Group for Electricity and Gas (2007). ERGEG Regional Initiatives. *ERGEG Annual Report*, March 2007: 1-36.

[23] European Regulators Group for Electricity and Gas (2008). The Regional Initiatives - Europe's Key to Energy Market Integration. *ERGEG Annual Report*, February 2008: 1-18.

[24] Fabrizio, K.R., Rose, N.L., Wolfram, C.D. (2007). Do Markets Reduce Costs? Assessing the Impact of Regulatory Restructuring on U.S. Electric Generation Efficiency. *American Economic Review* 97 (4): 1250-1277.

[25] Hall, R.E. (1988). The Relation between Price and Marginal Cost in the US Industry. *Journal of Political Economy* 96: 921-947.

[26] Harrison, A.E. (1994). Productivity, Imperfect Competition and Trade Reform, *Journal of International Economics* 36: 53-73.

[27] Hopenhayn, H.A. (1992). Entry, Exit, and Firm Dynamics in Long Run Equilibrium. *Econometrica* 60(5): 1127-50.

[28] Jamasb, T., Pollitt, M. (2005). Electricity Market Reform in the EU: Review of Progress toward Liberalization & Integration. *CEEPR Working Paper*, March 2005: 1-34.

[29] Joskow, P.L. (1997). Restructuring, Competition and Regulatory Reform in the US Electricity Sector. *Journal of Economic Perspectives*, 11 (3): 119-138.

[30] Joskow, P.L. (2003). Electricity Sector Restructuring and Competition: Lessons Learned. *CEEPR Working Paper* 03-014: 1-20.

[31] Joskow, P.L., Kahn, E. (2002). A Quantitative Analysis of Pricing Behavior in California's Wholesale Electricity Market during Summer 2000. *Energy Journal* 23 (4): 1-35.

[32] Joskow, P.L., Schmalensee, R. (1983). Markets for Power: An Analysis of Electrical Utility Deregulation. *University of Pennsylvania Law Review* 133 (1): 287-290.

[33] Konings, J., Van Cayseele, P., Warzynski, F. (2005). The effects of privatization and competitive pressure on firm's price-cost margins: Micro evidence from emerging economies. *Review of Economics and Statistics* 87 (1): 124 - 134.

[34] Konings, J., Vandenbussche, H. (2005). Antidumping Protection and Markups of Domestic Firms. *Journal of International Economics* 65 (1): 151-165.

[35] Konings, J. and H. Vandenbussche (2008). Heterogeneous Responses of Firms to Trade Protection. *Journal of International Economics* 76 (2): 371-383.

[36] Laffont, J.-J. (1994). The New Economics of Regulation Ten Years After. *Econometrica* 62 (3): 507-537.

[37] Laffont, J.-J., Tirole, J. (1993). A Theory of Incentives in Regulation and Procurement, *MIT Press.*

[38] Levinsohn, J. (1993). Testing the Imports-as-Market-Discipline Hypothesis. Journal of International Economics 35: 1–22.

[39] Levinsohn, J., Petrin, A. (2003). Estimating Production Functions Using Inputs to Control for Unobservables. *Review of Economic Studies* 70 (2): 317-341.

[40] Martins, J.O., Scarpetta, S. Pilat, D. (1996). Mark-Up Ratios in Manufacturing Industries: Estimates for 14 OECD Countries. *OECD Economics Department Working Papers* 162: 1-48.

[41] Olley, G., Pakes A. (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. Econometrica 64 (6): 1263-1297.

[42] Roberts, M. and J.D. Supina (1996). Output Price, Markups, and Producer Size," *European Economic Review* 40(3-5): 909-921.

[43] Roeger, W. (1995). Can Imperfect Competition Explain the Difference between Primal and Dual Productivity Measures? Estimates from the US Manufacturing. *Journal of Political Economy* 103: 316-330.

[44] Roeger, W., Warzynski, F. (2004). A Joint Estimation of Price-Cost Margins and Sunk Capital-Theory and Evidence from the European Electricity Industry. *Working Papers* 04-17, Aarhus School of Business, Department of Economics: 1-20.

[45] Roeller, L.-H., Delgado, J., Friederiszick, H.W. (2007). Energy: Choices for Europe. *Bruegel Blueprint Series*, Bruegel 2007, 1-73.

[46] Sapir, A. (1996). The Effects of Europe's Internal Market Program on Production and Trade: A First Assessment. *Review of World Economics* 132: 457-475.

[47] Smeers, Y. (2005). How Well Can One Measure Market Power in Restructured Electricity Systems? *CORE Discussion Papers* 2005/50: 1-70.

[48] Smeers, Y. (1997). Computable Equilibrium Models and the Restructuring of European Electricity and Gas Markets. *The Energy Journal* 18 (4): 1-31.

[49] Tybout, J. (2003). Plant- and Firm-level Evidence on "New" Trade Theories. In: Choi, K., Harrigan, J. (Eds.), The Handbook of International Trade 1, Oxford: Blackwell Publishing, UK and Cambridge, MA: 388-415.

[50] Van Biesebroeck, J. (2008). The Sensitivity of Productivity Estimates. *Journal of Business & Economic Statistics* 26: 311-328.

[51] Van Biesebroeck, J. (2007). Robustness of Productivity Estimates. *Journal of Industrial Economics* 55 (3): 529–569.

[52] Vandenbussche H., Zarnic, Z. (2008). US Safeguards on Steel and the Markups of EU Steel Producers. *Review of World Economics* 144 (3): 458-490.

[53] Wolak, F. (1994). An Economic Analysis of the Asymmetric Information, Regulator-Utility Interaction. *Annales d'Economie et de Statistique* 34 (1994): 13-69.

[54] Wolak, F. (2003). Measuring Unilateral Market Power in Wholesale Electricity Markets: The California Market, 1998-2000, *American Economic Review* 93: 425-430.

[55] Wolak, F. (2006). Unilateral Market Power in Wholesale Electricity Markets. *CESifo DICE Report* 2/2006: 10-14.

[56] Wolfram, C.D., 1999. Measuring Duopoly Power in the British Electricity Spot Market. American Economic Review 89 (4), 805-826.

Appendix A. Data

The data used in this study are the annual company accounts data reported at the end of each year, which are compiled from Amadeus organized by the Bureau van Dijk (May 2008). We carefully compile the data on variables that proxy for institutional reforms from the national statistical offices and official reports of European Commission. The composite indicators of market regulation are retrieved from the OECD data compiled by Conway and Nicoletti (2006). The additional annual data on control variables, i.e. the country-level real GDP growth rates, the real long-term interest rates, and the price index of investment goods, are obtained from the Ameco database from the ECFIN department at the European Commission. The product-level trade data are retrieved from Eurostat External Trade Database.

Regarding cleaning of the data, we exclude clearly wrong entries such as extremely high growth rates in employment, material or labour costs. We consider only those observations where the share of material costs and the share of labour costs in turnover is larger than 1 percent and smaller than 100 percent and exclude the extreme values of nominal growth in input and output. By doing so, we excluded roughly 2 percent of observations from the raw data. We consider only the firms that report active legal status to exclude the possibility that our results are affected by the firms in the consolidation process. Moreover, we consider only the firms from those countries for which we have comparable and complete information, that is, we are able to retrieve complete data for Austria, Belgium, Germany, France, Italy, Luxembourg, Norway, Portugal, Spain, and Sweden. We use only unconsolidated financial statements to avoid double-counting of firms and subsidiaries and thus focus on the local operations of firms and do not overestimate the values of variables. Since not all EU countries require consolidation of accounts for all firms, it increases the comparability of firms across countries. After cleaning, the firm-level dataset reported in the summary statistics and used in the analysis is representative as it on average accounts for 95 percent (92 percent) of the aggregate Eurostat data in terms of employment (sales) for the entire electricity sector.

Company-Accounts Variables

The data cover a representative sample of firms in the electricity sector across a set of European countries for which complete and comparable data are available for the period 1995-2007. The firms are identified at the 4-digit Nace Rev.1.1 industrial activity level. The data allow us to distinguish each firm's participation in generation, transmission and distribution of electricity, classified under Nace Rev.1.1 codes 4011-4013. We obtain the indication of their diversification by referring to their reported status in primary and secondary condes of industrial classification. A firm is considered to be diversified multi-product firm, if it reports its industrial activities also in other secondary codes outside the electricity sector.

The variables used in our econometric models are the following. The firm-level operating revenue in each year provided in Amadeus is used to proxy the output variable. We prefer operating revenues to sales, because they include realizations of previous stocks, however the direction and significance of results do not change substantially when using sales instead of revenues. For the value of capital we use the book value of tangible fixed assets for each firm in each year. The labour costs reported in Amadeus proxy the wage bill variable. The material costs variable is simply proxied by the firm-level total material costs consisting of the factor price multiplied by the quantity of materials.

We construct our capital variable in line with Konings et al. (2005) as the user cost of capital multiplied by its nominal value. We define the user value of capital as $Z_{jt}(r_{kt} + d_{jt})$, where we consider a country-level price index of investment goods Z_{jt}, a long-term real interest rate r_{kt} at time t for country k, and depreciation of capital, d_{jt}, of the average rate of 15 percent which is in line with the EC (2007a) stating that the average depreciation of capital in the electricity sector for EU15 lies between 10 and 20 percents. We simulated the sensitivity of price-cost margins towards different depreciation rates, price indices of investment goods, and real interest rates. Allowing for 5 percent changes, our point estimates vary within the range of 1 percent, without altering the signs of estimated coefficients.

Measures of Institutional Reforms, Market Concentration and Trade

Market concentration in the regression analysis is measured by the Herfindahl index, which is the sum of squared market share of firms in a given three-digit Nace Rev.1.1 industry. The time-series of the market share of the largest firm in the electricity sector depicted in Figure 7 is retrieved from the Eurostat structural data for the energy sector. The measure of availability of generator plants is computed as the share of electricity output provided by each type of generators in the total electricity output per each country and year, based on the Eurostat structural data on energy sector. The measure of trade arbitrage is the ratio of imports to the sum of domestic sales and imports in a given three-digit industry, based on the product-level trade data from Eurostat External Trade Database.

Several different variables at the national-sector and firm levels are constructed to proxy for institutional reforms in the econometric analysis. The EC Electricity Directives are defined in line with the EC official documents (EC 2007) and in Figures 1 to 6 depicted as vertical lines at the time of their initiation. The institutional variables are organized in different groups as used in Tables 4 and 5 and depicted by Figures 1 to 7.

The group labeled "*legal basis*" includes the following variables:

- "Legal basis" refers to the date of implementation of the first national Electricity Act.
- "Operating regulatory authority" refers to the date at which the country established an operating authority to regulate the national electricity market. The authority have begun to operate at the time of Electricity Act implementation (e.g. UK) or afterwards. The amendma refer to the national modifications of Electricity acts, where some countries made more frequent adjustments than the others. Therefore, the variable is computed at the 3-digit national-sector level as the age since the first operational year of the national regulatory authority.
- "OECD index of regulatory constraints", "Index of entry barriers" and "Index of government ownership" refer to the composite indices compiled by Conway and Nicoletti (2006), which are extended for 2005-2007 on the basis of the annual growth rates during a sufficiently long period 1975-2004. The indices are bounded by the interval [0,6], where higher values represent larger constraints of market regulation, entry barriers, and state ownership respectively. "OECD index of regulatory constraints" combines information in three main areas, i.e. state control, barriers to entry, and involvement in business operations. All of these regulatory data are vetted by Member country officials and/or OECD experts. The indicators are calculated using a bottom-up approach in which the regulatory data are quantified using an appropriate scoring algorithm. Further detailed information on construction and robustness of these indicators are reported by Conway and Nicoletti (2006).

The group labeled "*wholesale market access*" includes the following variables:

- "Organized market exchange" is measured by the age since the national organized exchange for electricity of suppliers has been in place. Austria established EXAA in 2000, Belgium

Belpex in 2006, Western Denmark joined in 1999 and Eastern Denmark in 2000 the Nord Pool, Finland joined the Nord Pool in 1998, France established Powernext in 2001, Italy Ipex in 2004, the Netherlands APX in 1999, Norway the Nord Pool in 1993, Portugal Mibel in 2004, Spain OMEL in 1998, Sweden joined the Nord Pool in 1996, England and Wales established the organized market in 1990 and since March 2001 formed NETA. The Greek and Luxembourgese wholesale electricity market were initiated in 2007. The Irish single electricity market (SEM) was agreed in 2004, but trading began in 2007.

The group labeled "*retail market access*" includes the following variables:

- "Industrial consumer switching" refers to the share of large industrial consumers that were able to switch between different electricity suppliers in a country. Computations of the time-invariant index are based on indicators of electricity retail market competition provided by Al-Sunaidy and Green (2006).

- "Retail market opening" is measured by the age since the initial opening of the national retail electricity market for the end consumers, which mainly refer to industrial consumers in most European countries. At these dates, consumers are given a choice to choose between different electricity suppliers. In the first years of initial opening for most European countries during 1998-2001, the share of consumer switching across the countries varied from low 2% (Belgium) and medium 10-30% (Austria, France, Germany, Ireland, Luxembourg, the Netherlands, Spain, Portugal) to over 50% (the Nord Pool and the UK) for the large industrial consumers. During the same period, switching of small industrial consumers and households was below 10% for most countries, except the Nord Pool and the UK (30-50%).

The group labeled "*bundling of electricity transmission and distribution*" includes the following variables:

- "OECD index of vertical integration" refers to a national-sector level indicator of the presence of vertically-integrated electricity firms. The index runs is bounded by the interval [0,6], where higher values representing higher constraints of market regulation. The detailed information on construction and robustness of the indicator is reported by Conway and Nicoletti (2006).

- "Firm-specific bundling" is a firm-level measure computed by using the information from Amadeus on the secondary industrial activities of each firm. It is a dummy variable taking value 1, if a firm reports its presence in both transmission and distribution of electricity. The variable captures strictly the bundling of electricity transmission and distribution at the firm-level.

The group labeled "*firm ownership*" includes the following variables:

- "Majority private" and "Majority foreign" are firm-level variables. The information on ownership is collected directly from the companies and retrieved from Amadeus database, which receives information from its providers from all European countries. This information is analyzed to identify each cross-border holding or subsidiary link by the national identification number of the companies involved. Besides the percentage share of direct owners, the ownership status also comprises information about the nationality of the ownership, private and foreign. The regression results in Table 4 and 5 using ownership status are based on lesser observations, because we drop from the analysis those firms for which we could not trace ownership information in the Amadeus data. This ensures that the information we use is a good measure of whether a firm is domestically privately owned, foreign-owned or state-owned. The ownership status does not vary and refers to the latest data collected, because the ownership status is only recorded at the time that the data are collected by Bureau Van Dyk. We therefore used two different CD-ROMS, the one referring to the data collected in the year 2007 and the other referring to the data collected in 2008 to trace the changes in ownership status.

The sources are the following. The information about national legislation, wholesale and retail markets is compiled from the official documents of national regulatory authorities, i.e. Electricity Regulatory Authority (E-Control) for Austria, Commission for Electricity and Gas Regulation (CREG) for Belgium, Energy Regulatory Authority (DERA) for Denmark, Energy Market Authority (EMV) for Finland, Electricity Regulation Commission (CRE) for France, Federal Network Agency for Electricity, Gas, Telecommunications, Posts and Railway (BnetzA) for Germany, Regulatory Authority for Energy (RAE) for Greece, Commission for Energy Regulation (CER) for Ireland, Regulatory Authority for Electricity and Gas (AEEG) for Italy, Luxembourg Institute for Regulation (ILR) for Luxembourg, Office of Energy Regulation (DTE) for the Netherlands, Norwegian Water Resources and Energy Directorate (NVE) for Norway, Energy Services Regulatory Authority (ERSE) for Portugal, National Energy Commission (CNE) for Spain, Swedish Energy Market Inspectorate for Sweden, Office of Gas and Electricity Markets (Ofgem) for the UK. Computations based on indicators of electricity retail market competition by Al-Sunaidy and Green (2006). The composite indices are retrieved from the OECD market regulation database, which is compiled by Conway and Nicoletti (2006).

Appendix B. The Baseline Model in Section 4.1

The firm-specific price markup over marginal cost is derived by following the approach developed by Roeger (1995) and among others applied by Konings and Vandenbussche (2005) and Vandenbussche and Zarnic (2008) to the firm-level data. Similar to Hall (1988), consider a log-linear homogeneous production function $Q_{it} = G(K_{it}, L_{it}, M_{it})E_{it}$ for output Q_{it}, where K_{it}, L_{it}, and M_{it} are capital, labor and material inputs, and E_{it} is a shift variable representing changes in productivity efficiency of a firm i at time t. This consideration is standard in literature (e.g. Hall 19888, Olley and Pakes 1996, Fabrizio et al. 2007), so that the function is of Cobb-Douglas type: $Q_{it} = G(K_{it}, L_{it}, M_{it})E_{it}$ or $Q_{it} = \exp(e_{it})K_{it}^{\alpha_K} L_{it}^{\alpha_L} M_{it}^{\alpha_M}$.

In order to account for simultaneity bias coming from the correlation between the TFP growth and production inputs, Hall (1998) uses instruments. The aggregate instruments are not plausible in our firm-level analysis, because there is no variation across firms and valid firm-level instruments are not available in our data. Roger (1995) circumvents this issue by subtracting the price-based from the output-based Solow residual, which leads to cancellation of the residual TFP term. Using the Solow residual (SR_{it}), Hall (1988) measures the productivity growth as the output growth net weighted growth of the production factors, described as:

$$SR_{it} = \triangle q_{it} - (\xi_{it} - \alpha_{Lit} - \alpha_{Mit}) \triangle k_{it} - \alpha_{Lit} \triangle l_{it} - \alpha_{Mit} \triangle m_{it} + \triangle e_{it} \tag{B.1}$$

where small letters refer to the logarithms and ξ_{it} denotes economies of scale parameter. Equation (B.1) considers the share of inputs in the firm operating revenues, where the shares of labor and material costs in total revenues ($P_{it}Q_{it}$) of a firm i at time t are denoted by $\alpha_{Lit} = \frac{F_{Lit}L_{it}}{P_{it}Q_{it}}$ and $\alpha_{Mit} = \frac{F_{Mit}M_{it}}{P_{it}Q_{it}}$ with the letters F and P denoting input and output prices. Decomposition of the markup and the technology component is a crucial step in the Roeger approach and (B.1) can be expressed in the following form:

$$SR_{it} = \mu_{it}(\triangle q_{it} - \triangle k_{it}) + (\xi_{it} - \mu_{it}) \triangle e_{it} \tag{B.2}$$

where $\mu_{it} = \frac{P_{it} - c_{it}}{P_{it}}$ is the Lerner index for a firm i at time t. The right-hand side is decomposed in the markup and the pure technology component.[27] In the output-based residual SR_{it}, the growth of firm's i revenues is denoted by Δq_{it} and the growth rate of capital by $\triangle k_{it}$ at time t. Similarly in the price-based residual SRP_{it}, the growth rates of capital costs and output prices are respectively denoted by ΔF_{Kit} and Δp_{it}. The price-based or the dual Solow residual (SRP_{it}) is then defined from the relationship between the marginal cost and the output price and it can be expressed in the following form:

$$\begin{aligned} SRP_{it} &= (\xi_{it} - \alpha_{Lit} - \alpha_{Mit}) \triangle F_{Kit} + \alpha_{Lit} \triangle F_{Lit} + \alpha_{Mit} \triangle F_{Mit} - \triangle p_{it} + \triangle e_{it} \\ &= (\xi_{it} - \mu_{it}) \triangle e_{it} - \mu_{it}(\triangle p_{it} - \triangle F_{Kit}) \end{aligned} \tag{B.3}$$

where F_{Kit} denotes the price of capital employed in the production function. The innovation of Roeger (1995) comes from using the dual Solow residual (SRP_{it}) to substitute for a change in productivity efficiency of a firm i at time t denoted by $\triangle e_{it}$ in (B.2). The advantage is that this method does not require instruments, which are large unavailable at the firm-level (but at aggregate level do not make sense due to little cross-firm variation). Subtracting the dual Solow

[27] Roeger (1995) shows that the change in the marginal cost ($\triangle c_{it}$) is a weighted average of the changes in input prices (F_{Iit}) with respect to their relative cost shares in the firm's cost function (ϕ_{Iit}), accounting for the change in technology (e_{it}), i.e. $\triangle c_{it} = \phi_{Iit} \triangle F_{Iit} - \triangle e_{it}$.

residual from the primal Solow residual with Lerner index λ_{it} is derived in the following manner:

$$\begin{gathered}(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle F_{Kit}) = \\ \frac{1}{\mu_{it}}[(\triangle q_{it} + \triangle p_{it}) - \alpha_{Lit}(\triangle l_{it} + \triangle F_{Lit}) - \alpha_{Mit}(\triangle m_{it} + \triangle F_{Mit}) \\ -(\xi_{it} - \alpha_{Lit} - \alpha_{Mit})(\triangle k_{it} + \triangle F_{kit})]\end{gathered}$$

$$\begin{gathered}\mu_{it}[(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle F_{Kit})] - [(\triangle q_{it} + \triangle p_{it}) + (\xi_{it} - \alpha_{Lit} - \alpha_{Mit})(\triangle k_{it} + \triangle F_{kit})] = \\ \alpha_{Lit}(\triangle l_{it} + \triangle F_{Lit}) + \alpha_{Mit}(\triangle m_{it} + \triangle F_{Mit})\end{gathered}$$

$$\begin{gathered}(\triangle q_{it} + \triangle p_{it}) - [(\xi_{it} - \alpha_{Lit} - \alpha_{Mit})(\triangle k_{it} + \triangle F_{kit}) + \alpha_{Lit}(\triangle l_{it} + \triangle F_{Lit}) + \alpha_{Mit}(\triangle m_{it} + \triangle F_{Mit})] = \\ \mu_{it}[(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle F_{Kit})]\end{gathered}$$

where the share of inputs (I_{it}) in total revenues ($P_{it}Q_{it}$) are denoted by $\alpha_{Iit} = \frac{F_{Iit}I_{it}}{P_{it}Q_{it}}$ with the letters F and P representing input and output prices. To obtain a price-cost margin term $\mu_{it} = \frac{P_{it}-c_{it}}{c_{it}}$, which can be directly estimated, one has to subtract the price-based residual SRP_{it} from the output-based residual SR_{it} as:

$$(\triangle q_{it} + \triangle p_{it}) - \sum_{I} \alpha_{Iit}\Delta F_{Iit} = \mu_{it}[(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle F_{Kit})] \tag{B.4}$$

Appendix C. The Model with Variable Capital in Section 4.2

Roeger and Warzynski (2004) point out that electricity firms could adopt more efficient ways to use the capital in generation of electricity. For example, firms could adopt more efficient techniques due to further deregulation of markets leading to increased competition. Technological improvements and further deregulation of European electricity markets could lead to reorganization of the capital stock, which would in turn reduce the use of fixed capital and free a fraction of variable capital for adjustments to changing market conditions. If this is the case, then the markup estimates should be controlled for the variable part of capital that responds to shifts in market conditions. If by contrast, the capital is considered as fully fixed, then the markup estimates will be biased upwards.

In what follows, we consider in line with Roeger and Warzynski (2004) that the total capital stock includes a fraction of capital that is adjusted to current demand and cost conditions. Within the log-linear homogeneous production function $Q_{it} = G(K_{it}, L_{it}, M_{it})E_{it}$, consider now that the capital stock $K_{it} = K^v_{it} + K^f_{it}$ includes both fixed capital K^f_{it} and variable capital input K^v_{it}. However, the share of variable capital is not directly observed in the data, hence Roeger and Warzynski (2004) propose a model that estimates the share of fixed capital in the production function. The model builds upon the Roeger (1995) approach with the markup term included in the TFP growth, but in addition exploits the bias in the TFP measurement proportional to the share of fixed capital. Similar to the Roeger (1995) model, define first the output-based and price-based Solow residuals, respectively SR^s_{it} and SRP^s_{it}, as:

$$\begin{aligned} SR^s_{it} &= \triangle q_{it} - (\alpha^s_{Kit} \triangle k_{it} + \alpha^s_{Lit} \triangle l_{it} + \alpha^s_{Mit} \triangle m_{it}) + \triangle e_{it} && \text{(C.1)} \\ SRP^s_{it} &= \alpha^s_{Kit} \triangle F_{Kit} + \alpha^s_{Lit} \triangle F_{Lit} + \alpha^s_{Mit} \triangle F_{Mit} - \triangle p_{it} - \triangle e_{it} && \text{(C.2)} \end{aligned}$$

where the fractions of input costs in total costs ($F_{Iit}I_{it}$) are denoted by $\alpha^s_{Kit} = \frac{F_{Kit}K_{it}}{F_{Iit}I_{it}}$, $\alpha^s_{Lit} = \frac{F_{Lit}L_{it}}{F_{Iit}I_{it}}$ and $\alpha^s_{Mit} = \frac{F_{Mit}M_{it}}{F_{Iit}I_{it}}$ with the letter F denoting input prices and I_{it} total inputs. The contribution of factors and their prices to output and output prices should be weighted with their respective shares in variable costs, however the variable costs are not directly observed in the data. Following Roeger and Warzynski (2004), we first identify the measure of variable capital and derive the model where the estimate of price-markup is controlled for the presence of variable capital.

Definition of Variable Capital

Within the log-linear homogeneous production function $Q_{it} = G(K_{it}, L_{it}, M_{it})E_{it}$, consider that the degree of variable capital $0 \leq s_{it} < 1$ within the capital stock K_{it} is defined as:

$$s_{it} = \frac{K^v_{it}}{K_{it}} = \frac{K^v_{it}}{K^v_{it} + K^f_{it}} \tag{C.3}$$

Assume that production function is a type of Leontief production function with production inputs N_{it} and K^v_{it} used in fixed proportions, so that $N_{it} = \frac{\alpha_{Kit}}{\alpha_{Lit}} K^v_{it}$:

$$Q^s_{it} = \min(\alpha_{Lit} L_{it}, \alpha_{Kit} K^v_{it}) - K^f_{it} \tag{C.4}$$

The fractions of variable s_{it} and fixed capital $(1 - s_{it})$ are not directly observed in the data. Roeger and Warzynski (2004) show that the share of variable capital s_{it} varies with the firm size and economic activity and suggest to use measured labor productivity as its proxy. We adopt their assumption that both labor productivity and the variable capital share are increasing functions of output and thus labour productivity can be used as a proxy for variable capital share s_{it}. To clarify this relationship, define labour productivity as $x_{it} = \frac{Q^s_{it}}{N_{it}}$ using the above production function Q^s_{it} and derive the relationship between the growth rate of variable capital Δk^v_{it} and labour productivity $x_{it}(s_{it})$ using the observed information on total capital stock K_{it}, as:

$$\begin{aligned} x_{it} &= \alpha_{Lit} - \frac{K^f_{it}}{L_{it}} = \alpha_{Lit} - \frac{\alpha_{Lit}K^f_{it}}{\alpha_{Kit}K^v_{it}} \\ &= \alpha_{Lit} + \frac{\alpha_{Lit}}{\alpha_{Kit}}(\frac{s_{it}-1}{s_{it}}) \quad , \ where \ \frac{K^f_{it}}{K^v_{it}} = \frac{1}{s_{it}} - 1 \end{aligned}$$

In the final step, differentiate $K^v_{it} = s_{it}K_{it}$, which leads to:

$$\frac{dK^v_{it}}{dt} = \frac{ds_{it}}{dx_{it}}\frac{dx_{it}}{dt}K_{it} + s_{it}\frac{dK_{it}}{dt}$$

$$\frac{dK^v_{it}}{dt}/K^v_{it} = \frac{ds_{it}}{dx_{it}}\frac{dx_{it}}{dt}\frac{K_{it}}{K^v_{it}} + s_{it}\frac{dK_{it}}{dt}$$

$$\Delta k^v_{it} = \frac{ds_{it}}{dx_{it}}\frac{dx_{it}}{dt}\frac{1}{s_{it}} + \Delta k_{it}$$

$$\Delta k^v_{it} = \frac{ds_{it}}{dx_{it}}\frac{dx_{it}}{s_{it}}\frac{dx_{it}}{dt}/x_{it} + \Delta k_{it}$$

$$\Delta k^v_{it} = \varepsilon_{sx}\Delta x_{it} + \Delta k_{it} \tag{C.5}$$

The variable capital is not directly observed in the data and Roeger and Warzynski (2004) suggest to express its growth rate in terms of measured labor productivity growth, Δx_{it}, and observable capital input, Δk_{it}. The growth rate of variable capital input is: The growth rate of variable capital Δk^v_{it} in (C.5), where Δk^v_{it} is proportional to growth of total capital growth Δk_{it} and labour productivity growth Δx_{it} weighted by the elasticity of the variable capital share with respect to labor productivity. We use this expression further in the analysis to derive the variable-cost based Solow residuals, specified as:

$$\triangle q_{it} = \frac{F_{Kit}K_{it}}{C^v_{it}} \triangle k^v_{it} + \frac{F_{Lit}L_{it}}{C^v_{it}} \triangle l_{it} + \frac{F_{Mit}M_{it}}{C^v_{it}} \triangle m_{it} + \triangle e_{it} \tag{C.6}$$

$$\triangle p_{it} = \frac{F_{Kit}K_{it}}{C^v_{it}} \triangle F_{Kit} + \frac{F_{Lit}L_{it}}{C^v_{it}} \triangle F_{Lit} + \frac{F_{Mit}M_{it}}{C^v_{it}} \triangle F_{Mit} - \triangle e_{it} \tag{C.7}$$

where the shares of input costs in total costs, $C_{it} = F_{Iit}I_{it}$, are denoted by $\alpha^s_{Kit} = \frac{F_{Kit}K_{it}}{F_{Iit}I_{it}}$, $\alpha^s_{Lit} = \frac{F_{Lit}L_{it}}{F_{Iit}I_{it}}$ and $\alpha^s_{Mit} = \frac{F_{Mit}M_{it}}{F_{Iit}I_{it}}$ with the letter F_{it} denoting input prices and I_{it} total inputs.

Identification of Variable Capital

The variable capital K^v is not directly observable. Consider the function of the firm variable costs, C^v_{it}, specified as:

$$C^v_{it} = C_{it} - C^f_{it} = C_{it} - (1 - s_{it})F_{Kit}K_{it} \tag{C.8}$$

$$\frac{C^v_{it}}{C_{it}} = [1 - (1 - s_{it})\frac{F_{Kit}K_{it}}{C_{it}}] \tag{C.9}$$

The expression (C.9) is then further used to derive the primal Solow residual weighted by the input shares in total costs in the following manner:

$$
\begin{aligned}
\frac{F_{Kit}K^v_{it}}{C_{it}} \triangle k^v_{it} &= \frac{F_{Kit}K^v_{it} + (F_{Kit}K_{it} - F_{Kit}K_{it})}{C_{it}} \triangle k^v_{it} \text{ ; } where\ K^v_{it} = s_{it}K_{it} \\
&= \frac{F_{Kit}K_{it}}{C} \triangle k^v_{it} + \frac{F_{Kit}(K^v_{it} - K_{it})}{C_{it}} \triangle k^v_{it} \\
&= \frac{F_{Kit}K_{it}}{C_{it}} \triangle k^v_{it} + \frac{F_{Kit}K_{it}(s_{it} - 1)}{C_{it}} \triangle k^v \\
&= \frac{F_{Kit}K_{it}}{C_{it}} \triangle k^v_{it} - (1 - s_{it})\frac{F_{Kit}K_{it}}{C_{it}} \triangle k^v_{it};\ \text{where } \Delta k^v_{it} = \varepsilon_{sx}\Delta x_{it} + \Delta k_{it} \\
&= \frac{F_{Kit}K_{it}}{C_{it}}(\varepsilon_{sx}\Delta x_{it} + \Delta k_{it}) - (1 - s_{it})\frac{F_{Kit}K_{it}}{C_{it}}(\varepsilon_{sx}\Delta x_{it} + \Delta k_{it})
\end{aligned}
$$

$$
[1-(1-s_{it})\frac{F_{Kit}K_{it}}{C_{it}}]\triangle q_{it} = \frac{F_{Kit}K^v_{it}(1 + s_{it} - s_{it})}{C_{it}}(\varepsilon_{sx}\Delta x_{it}+\Delta k_{it})+\alpha^s_{Lit}\triangle l_{it}+\alpha^s_{Mit}\triangle m_{it}+\frac{C^v_{it}}{C_{it}}\triangle e_{it}
$$

$$
\begin{aligned}
& \triangle q_{it} - \alpha^s_{Kit}\Delta k_{it} - \alpha^s_{Lit} \triangle l_{it} - \alpha^s_{Mit} \triangle m_{it} \\
= \ & (1 - s_{it})\alpha^s_{Kit} \triangle q_{it} + \frac{F_{Kit}(K^v_{it} - K_{it})}{C_{it}}\Delta k_{it} + \frac{C^v_{it}}{C_{it}} \triangle e_{it} \\
= \ & (1 - s_{it})(\triangle q_{it} - \triangle k_{it}) + \alpha^s_{Kit}\varepsilon \triangle x_{it} - (1 - s_{it})\alpha^s_{Kit}\varepsilon_{sx} \triangle x_{it} + \frac{C^v_{it}}{C_{it}} \triangle e_{it}
\end{aligned}
$$

$$
SRQ^s_{it} = (1 - s_{it})(\triangle q_{it} - \triangle k_{it}) + s_{it}\alpha^s_{Kit}\varepsilon_{sx} \triangle x_{it} + \frac{C^v_{it}}{C_{it}} \triangle e_{it} \tag{C.10}
$$

Equation (C.10) is directly comparable to the result of Warzynski and Roeger (2004). A similar logic is used to retrieve the price-based Solow residual weighted by the input shares in total costs, that is:

$$
\triangle p_{it} - \alpha^s_{Kit}\Delta F_{Kit} - \alpha^s_{Lit} \triangle F_{Lit} - \alpha^s_{Mit} \triangle F_{Mit} = (s_{it} - 1)(\triangle p_{it} - \triangle F_{Kit})\alpha^s_{Kit} + \frac{C^v_{it}}{C_{it}} \triangle e_{it}
$$

$$
SRP^s_{it} = (s_{it} - 1)(\triangle p_{it} - \triangle F_{Kit})\alpha^s_{Kit} + \frac{C^v_{it}}{C_{it}} \triangle e_{it} \tag{C.11}
$$

Subtraction of the primal Solow residual (C.10) from the price-based Solow residual (C.11) gives the expression:

$$
SRQ^s_{it} - SRP^s_{it} = [1 - s_{it}]\alpha^s_{Kit}[(\triangle q_{it} + \triangle p_{it}) - (\triangle k_{it} + \triangle r_{it})] + s_{it}\alpha^s_{Kit}\varepsilon_{sx} \triangle x_{it} \tag{C.12}
$$

The testable econometric model with variable capital costs can be expressed as $\triangle Y^s_{it} = \sigma_{it} \triangle X^s_{it}$. The left-hand side variable ($\triangle Y^s_{it}$) represents the growth rate in revenues per value of input costs weighted by their shares in total costs and the right-hand side explanatory variable ($\triangle X^s_{it}$) represents the growth rate in revenues per capital weighted by the share of capital in total costs of a firm i at time t. In the next step, the relationship between labour productivity x_{it} and the share of variable capital s_{it} is described by a nonlinear logistic function defined by Roeger and Warzynski (2004) as:

$$
s_{it} = [1 + \exp(s_o + s_1 x_{it} + u_{it})]^{-1} \text{ ; where } u_{it} \text{ is an error term} \tag{C.13}
$$

Appendix D. PCM Model in Section 5.1.2

The price-cost margins are estimated directly by using the observable firm data in a price-cost margin approach discussed in Tybout (2003) and in a similar way used by Wolak (2003), which is based upon a theoretical pricing model with imperfect competition. This approach defines the Lerner index $\lambda_{it} = \frac{P_{it} - c_{it}}{P_{it}}$, describing the marginal costs c_{it} of a profit-maximizing firm at time t as a decreasing function of the price elasticity of demand (ε_{it}) that a firm i faces when selling the output Q_{it} at price P_{it} at time t, formally expressed as $\frac{P_{it} - c_{it}}{c_{it}} = \frac{1}{\varepsilon_{it}}$. Following Tybout (2003), the price-cost margin (pcm_{it}) of firm i at time t is then expressed as a function of the output price (P_{it}), output (Q_{it}), and marginal production costs (c_{it}):

$$pcm_{it} = \frac{(P_{it} - c_{it})\, Q_{it}}{P_{it} Q_{it}} = \frac{(P_{it} - c_{it})}{P_{it}} \tag{D.1}$$

We follow the common estimation approach discussed in Konings and Vandenbussche (2005) and use the observed firm-level price-cost margin defined as firm's i operating revenues net of expenditures on labor ($F_{Lit} L_{it}$) and materials ($F_{Mit} M_{it}$) over operating revenues at year t, i.e.

$$pcm_{it} = \frac{(P_{it} Q_{it} - F_{Mit} M_{it} - F_{Lit} L_{it})}{P_{it} Q_{it}} \tag{D.2}$$

which leads to the following econometric specification:

$$pcm_{it} = \alpha_i + \delta_1 Z_{it} + \xi_{it} \tag{D.3}$$

where α_i represents the unobserved firm specific fixed effects and ξ_{it} a white noise error term. The literature (e.g. Vandenbussche and Konings 2005) suggests to include further controls captured by Z_{it}, such as capital intensity (KI_{it}) of firm i at time t defined as tangible over total assets, the real GDP growth (GDP_{jt}) in country j at time t, and annual fixed effects (D_t) to control for any macro-economic effects common to all firms. An alternative would be to use the observable data from the electricity spot markets to directly estimate the price-cost margins, following Borenstein et al (2002) and Fabrizio et al. (2007) applied to the UK and California. Unfortunately, we do not have sufficiently long time-series for the majority of European spot markets. We thus directly estimate price-cost margins by using comprehensive annual company-accounts data for a representative group of European firms in the electricity sector.

Appendix E. The Use of Olley-Pakes Model in Section 5.1.2

Olley and Pakes (1996) model like Roeger (1995) builds upon a production function framework that allows identification of markup by using the notion that under imperfect competition growth in inputs leads to disproportional growth in output. As noted previously, a key issue that emerges in the estimation of production functions is the possible simultaneity problem between input choice and productivity yielding inconsistent estimates. Unlike Hall (1988), Olley and Pakes (1996) method does not require any instruments to control for unobserved productivity. The price-cost margin term under imperfect competition is then the growth rate of output not accounted for the growth rate of inputs, which is controlled for the unobserved productivity shock.

Based on a behavioral framework, the Olley and Pakes (1996) method solves the simultaneity problem by using the firm-level investment decision to proxy for unobserved productivity shocks and controls for the endogenous firm exit from the sample by incorporating a decision rule into a dynamic model of firm behavior. The model assumes the following Cobb-Douglas production function with all variables in small letters expressed in logarithms as:

$$q_{it} = \beta_0 + \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + e_{it} \tag{E.1}$$

$$\text{where } e_{it} = \omega_{it} + \eta_{it}$$

where the output of firm i at time t, y_{it}, is a function of labor, l_{it}, materials, m_{it}, and capital, k_{it}. The firm-specific error term, e_{it}, has two components, a white noise component, η_{it}, and a time varying productivity shock, ω_{it}, which is known to the firm but unobservable to the econometrician. This productivity shock, ω_{it}, is a state variable that can impact the firm's choice of variable labor, l_{it}, and materials, m_{it}, leading to simultaneity problems. Moreover, capital is a state variable, only affected by the current and past values of unobserved productivity, ω_{it}. Investment is calculated as a function of capital with depreciation rate δ_{it} and it is specified as:

$$I_{it} = K_{it+1} - (1 - \delta_{it})K_{it}$$

Hence, the firm investment decisions depend on capital and productivity, formulated as $I_{it} = i_t(k_{it}, \omega_{it})$. A crucial assumption of the Olley and Pakes (1996) method is that the firm-level investments are positive, $I_{it} > 0$, so that the investment decision can be inverted to express unobserved productivity as a function of the observable capital and investment that are used to proxy for ω_{it} in (E.1) with $g_t = i_t^{-1}(k_{it}, \omega_{it})$:

$$\omega_{it} = g_t(k_{it}, I_{it}) \tag{E.2}$$

Recall Equation (B.3) in our baseline model and rewrite (E.1) by adjusting the shares of inputs in total revenues as:

$$\Delta q_{it} = \alpha_{Iit}\Delta I_{it} + e_{it} = \alpha_{Lt}\Delta l_{it} + \alpha_{Mit}\Delta m_{it} + \alpha_{Kt}\Delta k_{it} + \Delta\omega_{it} + \eta_{it} \tag{E.3}$$

where the shares of capital, labor and material costs in total revenues ($P_{it}Q_{it}$) of a firm i at time t are denoted by $\alpha_{Kit} = \frac{F_{Kit}K_{it}}{P_{it}Q_{it}}$, $\alpha_{Lit} = \frac{F_{Lit}L_{it}}{P_{it}Q_{it}}$ and $\alpha_{Mit} = \frac{F_{Mit}M_{it}}{P_{it}Q_{it}}$ with the letters F and P denoting input and output prices. Consider (E.2) and differentiate a time varying productivity shock, ω_{it}, as:

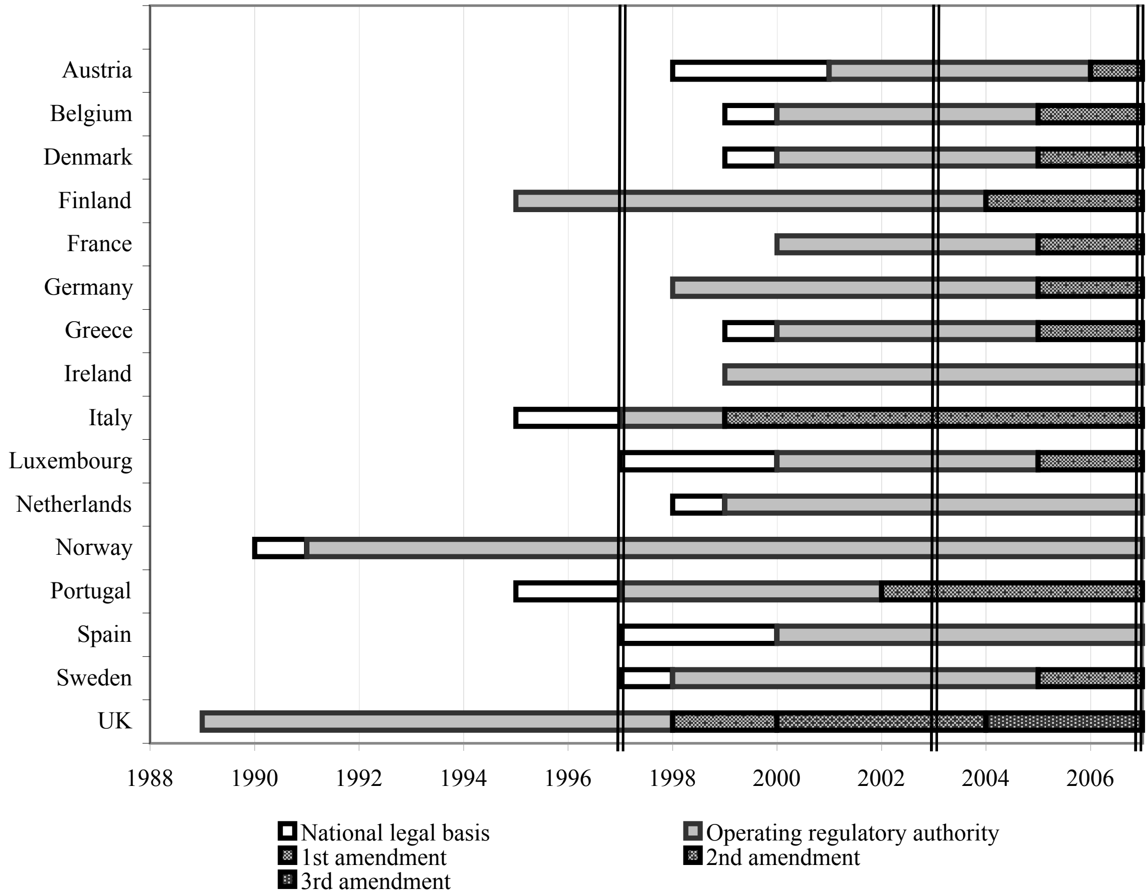
$$\Delta\omega_{it} = g_t(k_{it}, I_{it}) - g_t(k_{it-1}, I_{it-1}) \tag{E.4}$$

Equation (E.4) expresses the unobservable change of productivity shock as a function of observable capital and investment. Olley and Pakes (1996) suggest an algorithm to proxy for this function by a polynomial in capital and investment, $\phi_{it}(k_{it-n}, ..., k_{it}, I_{it-n}, ..., I_{it})$ *with* $n = 1, .., N$, in order to control for the unobserved productivity when estimating the price-cost margin. Practically, the length of polynomial depends on the time span of the data and typically it is sufficient to use the fourth-order polynomial, that is $n = 1, .., 4$. Substituting (E.4) into (E.3) gives a testable econometric model to estimate the price-cost margin by controlling for unobserved productivity shock as:

$$\Delta y_{it} = a_i + \mu_{it} \Delta q_{it} + \phi_{it}(\cdot) + \eta_{it} \tag{E.5}$$

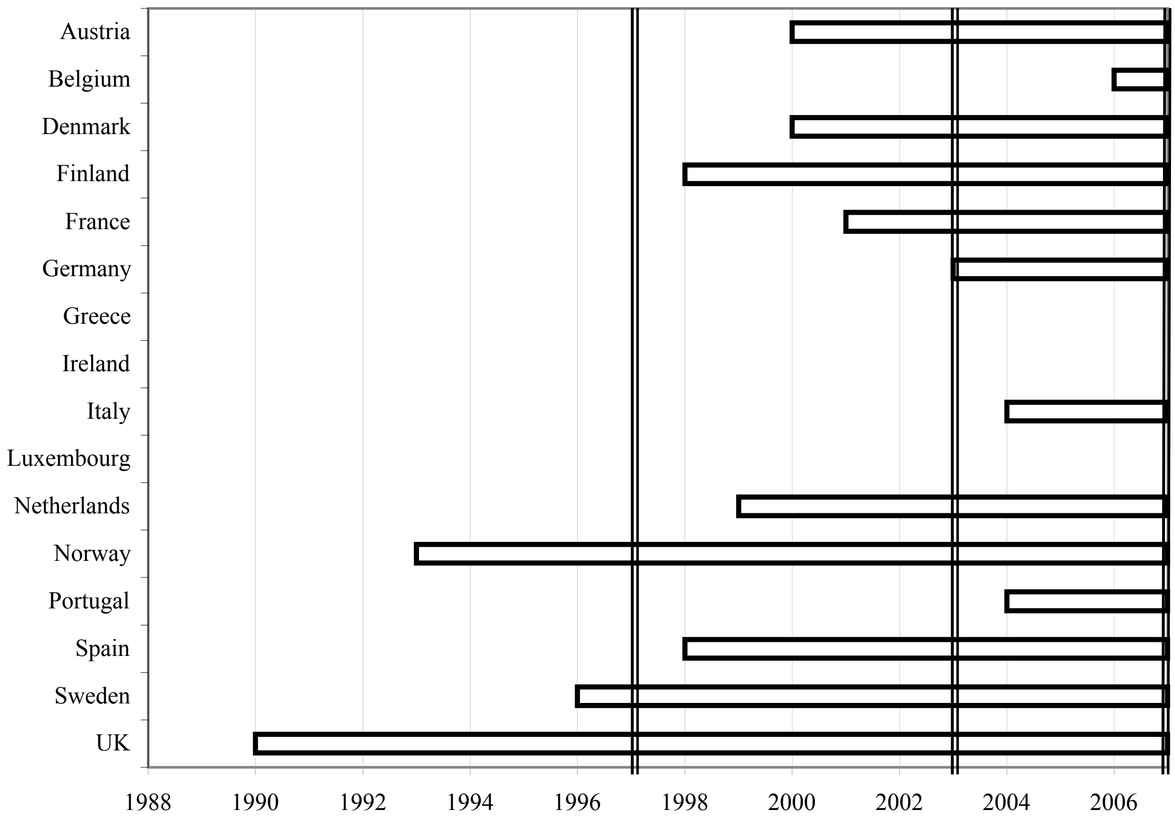
where the left-hand side of (E.5) represents the output growth adjusted for the growth in labor and material inputs of firm i at time t, that is $\Delta y_{it} = \Delta q_{it} - \alpha_{Lt} \Delta l_{it} - \alpha_{Mit} \Delta m_{it}$, $\phi_{it}(\cdot)$ denotes the polynomial in capital and investment including present and past values, a_i denotes the firm-specific effect and η_{it} denotes the white noise error term. A disadvantage of the Olley and Pakes method comes from the construction of the polynomial. Practically this requires that only non-negative values of investment are used for the consecutive time-series of the firm-level data, which typically truncates the sample of data used in the analysis.

Figure 1. Timeline of national legal basis



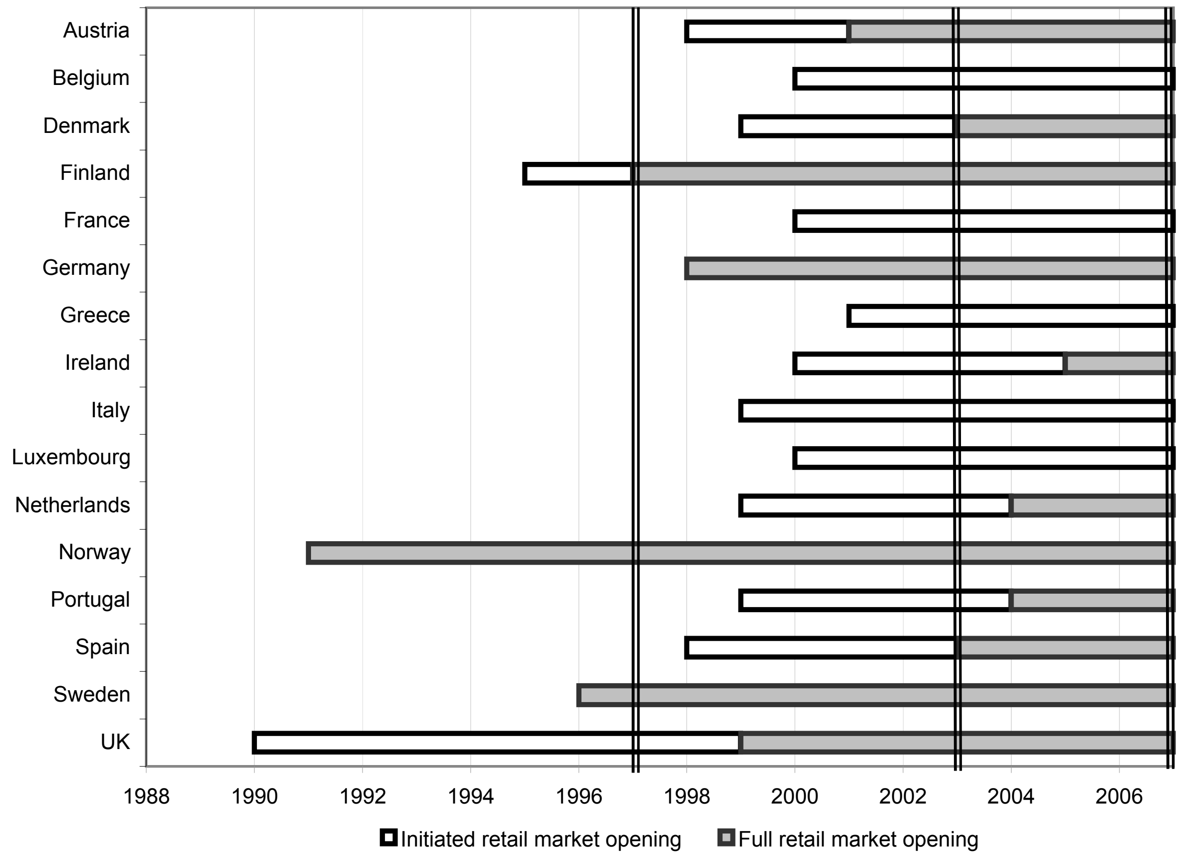
Notes: National legal basis refers to the date of implementation of the first national Electricity Act. Operating regulatory authority refers to the date since which the country had an operating authority to regulate the national electricity market. The authority have begun to operate at the time of Electricity Act implementation (e.g. UK) or afterwards denoted by grey bar. The amendma refer to the national modifications of Electricity acts, where some countries made more frequent adjustments than the others. The vertical lines depict the timelines of three EC liberalisation directives in 1997, 2003 and 2007. Sources are described in Data Appendix.

Figure 2. Timeline of wholesale market opening



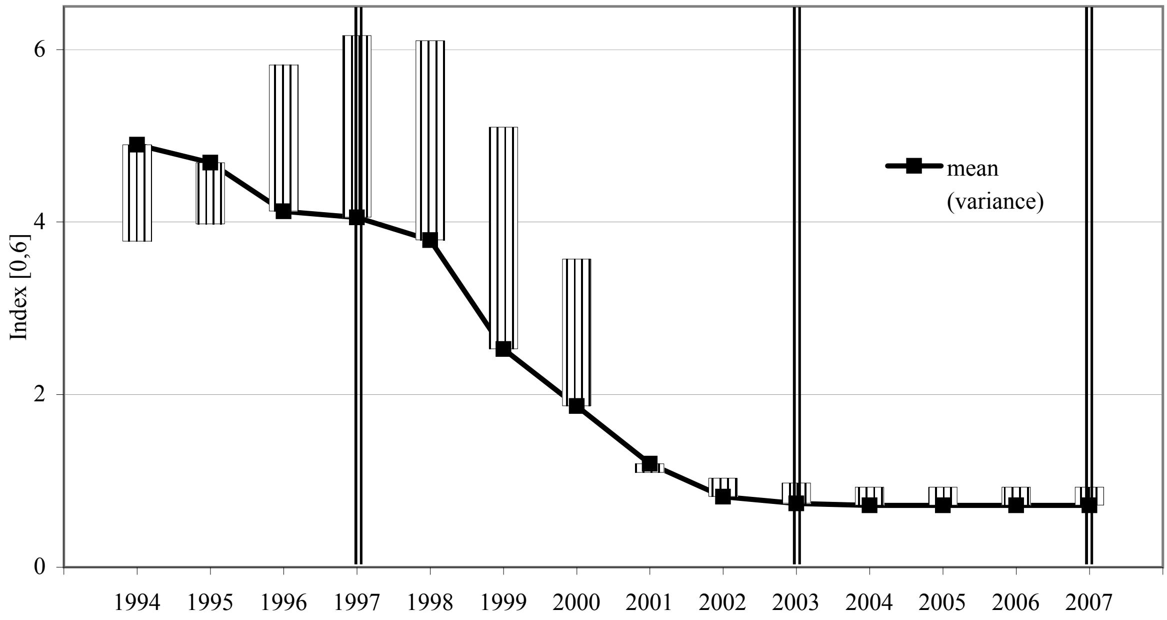
Notes: Establishment year of organized wholesale market exchange plots the timeline showing the date since which the organized exchange for electricity of suppliers has been in place. Austria established EXAA in 2000, Belgium Belpex in 2006, Western Denmark joined in 1999 and Eastern Denmark in 2000 the Nord Pool, Finland joined the Nord Pool in 1998, France established Powernext in 2001, Italy Ipex in 2004, the Netherlands APX in 1999, Norway the Nord Pool in 1993, Portugal Mibel in 2004, Spain OMEL in 1998, Sweden joined the Nord Pool in 1996, England and Wales established the organized market in 1990 and since March 2001 formed NETA. The Greek and Luxembourgese wholesale electricity market were inititated in 2007. The Irish single electricity market (SEM) was agreed in 2004, but trading began in 2007. The vertical lines depict the timelines of three EC liberalisation directives in 1997, 2003 and 2007. Sources are described in Data Appendix.

Figure 3. Timeline of retail market opening



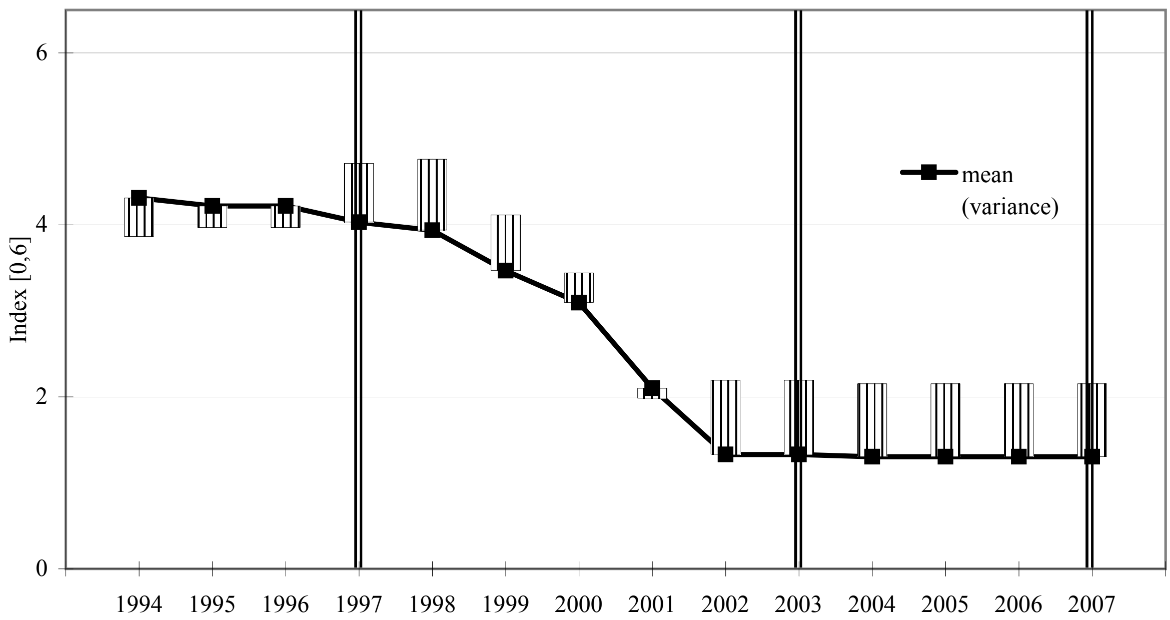
Notes: Figure indicates situation for retail market competition by plotting on the timeline the beginning of retail market opening and complete market opening, when most consumers are able to switch between electrcity suppliers. At these dates, consumers are given a choice to choose between different electricity suppliers. In the first years of initial opening for most European countries during 1998-2001, the share of counsumer switching across the countries varied from low 2% (Belgium) and medium 10-30% (Austria, France, Germany, Ireland, Luxembourg, the Netherlands, Spain, Portugal) to over 50% (the Nord Pool and the UK) for the large industrial consumers. During the same period, switching of small industrial consumers and households was below 10% for most countries, except the Nord Pool and the UK (30-50%). The vertical lines depict the timelines of three EC liberalisation directives in 1997, 2003 and 2007. Sources are described in Data Appendix.

Figure 4. Index of entry barriers, EU15 and Norway



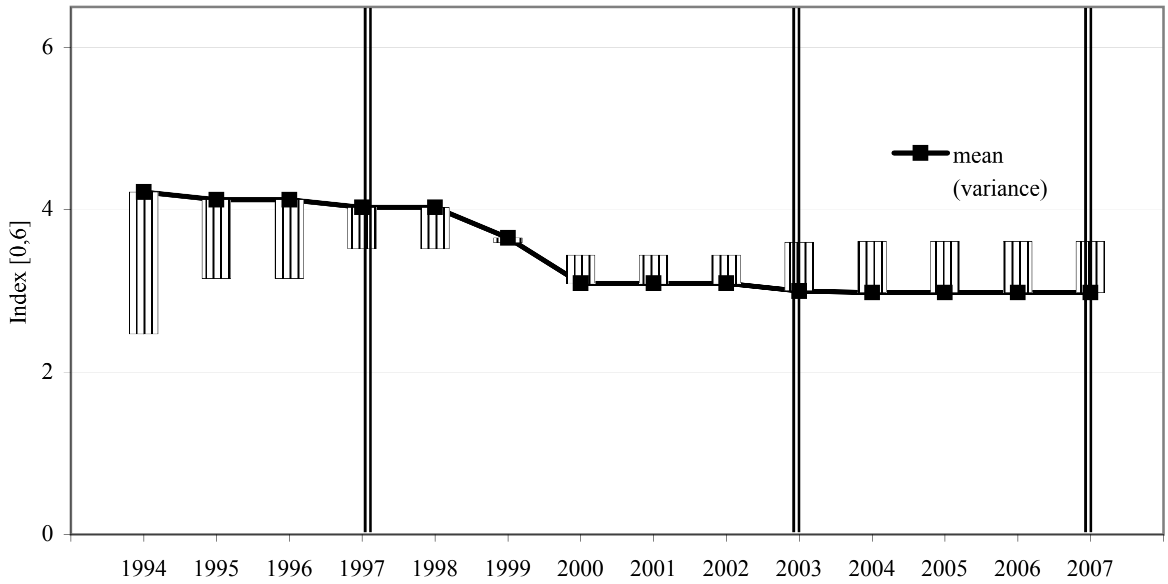
Notes: The index runs from [0,6] and the values for 2005-2007 are estimated using annual growth rates. The vertical lines depict the timelines of three EC liberalisation directives in 1997, 2003 and 2007. Source: Author's calculations based on the OECD data by Conway and Nicolletti (2006).

Figure 5. Index of vertical integration, EU15 and Norway



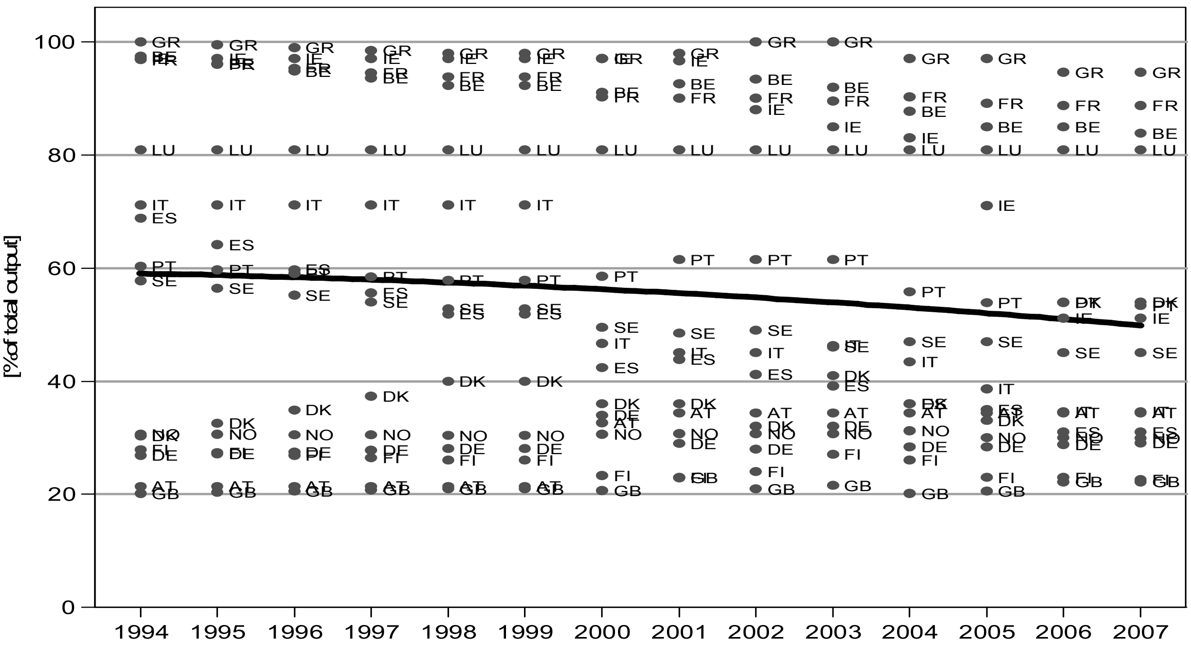
Notes: The index runs from [0,6] and the values for 2005-2007 are estimated using annual growth rates. The vertical lines depict the timelines of three EC liberalisation directives in 1997, 2003 and 2007. Source: Author's calculations based on the OECD data by Conway and Nicolletti (2006).

Figure 6. Index of government ownership, EU15 and Norway



Notes: The index runs from [0,6] and the values for 2005-2007 are estimated using annual growth rates. The vertical lines depict the timelines of three EC liberalisation directives in 1997, 2003 and 2007. Source: Author's calculations based on the OECD data by Conway and Nicolletti (2006).

Figure 7. Market share of the largest firm as percentage of total output, EU15 and Norway



Notes: The values before 1998 are estimated using the annual growth rates. The fitted regression line plots the European average across EU15 and Norway for each specific year. Source: Author's calculations based on the Eurostat (2008) structural data for the electricity sector.

Table 1. Summary statistics

	Full sample (1995-2007)	Before the 2nd EC directive (1995-2002)	After the 2nd EC directive (2003-2007)
Total observations	5273	1964	3309
Firms	676	433	821
	(3.064)	(3.697)	(1.453)
Employment	165	174	160
	(15.738)	(35.269)	(13.817)
Sales	105636	85086	117351
	(9101)	(15909)	(11040)
K/L	2645	3584	2088
	(367)	(748)	(379)
Labor costs	6.206	6.186	6.218
	(0.032)	(0.049)	(0.042)
Material costs	7.384	7.149	7.523
	(0.042)	(0.065)	(0.055)
ROA	6.923	6.506	7.170
	(0.142)	(0.214)	(0.187)
Lerner index	0.416	0.437	0.403
	(0.003)	(0.005)	(0.004)

Notes: Variables are expressed in thousands of Euros in real terms where applicable. Mean values of variables are reported with standard errors in brackets. The dataset is unbalanced panel with the number of firms varying over years. Employment refers to number of employees. Capital intensity (K/L) refers to total fixed assets over the number of employees. The Lerner index is calculated by the PCM method (Tybout 2003) as the value added over sales. ROA denotes returns on total assets. Regarding the representativeness of the dataset, the firm-level data correspond closely to comparable aggregated data by Eurostat (2008) as the firm-level data on average cover 95% of the aggregate data in terms of employment and 92% in terms of sales.

Table 2. Estimation results: Cross-border trade arbitrage and market concentration

	Baseline Model	Robustness Checks			
	Roeger (1)	Variable Capital (2)	Roeger (CRS) (3)	PCM (4)	Olley-Pakes (5)
Price-cost margin	0.445	0.417	0.505	0.437	0.585
	(0.023)***	(0.020)***	(0.022)***	(0.141)***	(0.043)***
Effect of market concentration	0.446	0.365	0.427	0.024	0.335
	(0.071)***	(0.058)***	(0.068)***	(0.038)	(0.150)**
Effect of trade arbitrage	-0.245	-0.212	-0.214	0.119	-0.236
	(0.035)***	(0.030)***	(0.033)***	(0.181)	(0.091)***
GDP	0.020	-0.012	-0.005	-0.004	0.004
	(0.056)	(0.003)***	(0.053)	(0.001)***	(0.000)***
Year * Country effects	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000
R-squared	0.591	0.380	0.674	0.549	0.553
Observations	5273	5273	5273	5273	2635

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. The main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The validity of the regression model is confirmed by the F-test in all specifications. Variables are described in Data Appendix.

Table 3. Effect of the second EC liberalisation directive in 2003 on price-cost margins

	Baseline Model		Robustness Checks					
	Roeger		Variable Capital		Roeger (CRS)		Olley-Pakes	
	1995-2002 (1)	2003-2007 (2)	1995-2002 (3)	2003-2007 (4)	1995-2002 (5)	2003-2007 (6)	1995-2002 (7)	2003-2007 (8)
Price-cost margin	0.531	0.413	0.389	0.357	0.585	0.476	0.658	0.562
	(0.038)***	(0.033)***	(0.029)***	(0.027)***	(0.036)***	(0.031)***	(0.069)***	(0.041)***
Effect of market concentration	0.368	0.505	0.331	0.526	0.304	0.541	0.193	0.073
	(0.115)***	(0.121)***	(0.082)***	(0.080)***	(0.110)***	(0.114)***	(0.234)	(0.315)
Effect of trade arbitrage	-0.299	-0.199	-0.158	-0.178	-0.261	-0.181	-0.257	-0.156
	(0.062)***	(0.048)***	(0.048)***	(0.038)***	(0.060)***	(0.046)***	(0.117)**	(0.074)**
GDP	-0.090	0.102	-0.010	-0.015	-0.078	-0.019	1.358	0.748
	(0.170)	(0.127)	(0.005)**	(0.003)***	(0.162)	(0.120)	(0.339)***	(0.236)***
Year * Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob (s1=s2) > chi2	0.258		0.155		0.268		0.869	
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.660	0.660	0.358	0.389	0.719	0.735	0.518	0.637
Observations	1964	3309	1964	3309	1964	3309	1018	1617

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. The main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The 2nd EC Directive on liberalisation of the European electricity sector was initiated in 2003, therefore we report estimations for two sub-samples, from the beginning of our data 1995 until 2003 and from 2003 until the end of available time series in 2007. In all specifications we reject the null hypothesis [Prob (H0: s1=s2) > chi2] that the estimates of price-cost margins are equal before and after 2003, which implies that the price-cost margins between 2 subsamples are statistically different from eachother. The validity of the regression model is confirmed by the F-test in all specifications. Variables are described in Data Appendix.

Table 4. Effect of different institutional measures on price-cost margins (Baseline Roeger model)

	Legal Basis		**Market Barriers**	**Wholesale Market Access**	**Retail Market Access**		**Bundling**
	Operating Authority	National Legislation	OECD Index of Regulatory Constraints	Organized Market Exchange	Switching of large industrial consumers	Retail Market Opening	OECD Index of Vertical Integration
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Price-cost margin	0.460	0.448	0.393	0.429	0.504	0.436	0.425
	(0.036)***	(0.035)***	(0.044)***	(0.034)***	(0.061)***	(0.031)***	(0.042)***
Effect of institutional measure	-0.010	-0.009	0.066	-0.007	-0.169	-0.070	0.045
	(0.003)***	(0.002)***	(0.008)***	(0.002)***	(0.031)***	(0.016)***	(0.006)***
Effect of market concentration	0.467	0.456	0.161	0.380	0.494	0.310	0.221
	(0.072)***	(0.072)***	(0.078)**	(0.074)***	(0.074)***	(0.077)***	(0.075)***
Effect of import penetration	-0.204	-0.169	-0.111	-0.175	-0.269	-0.166	-0.124
	(0.042)***	(0.039)***	(0.047)**	(0.040)***	(0.078)***	(0.039)***	(0.046)***
Year * Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.618	0.618	0.626	0.618	0.601	0.618	0.626
Observations	5273	5273	5273	5273	4978	5273	5273

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. GDP is included and the main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The validity of the regression model is confirmed by the F-test in all specifications. Variables of institutional measures are described in Data Appendix.

Table 5. Effect of different institutional measures on price-cost margins (Variable capital model)

	Legal Basis		**Market Barriers**	**Wholesale Market Access**	**Retail Market Access**		**Bundling**
	Operating Authority	National Legislation	OECD Index of Regulatory Constraints	Organized Market Exchange	Switching of large industrial consumers	Retail Market Opening	OECD Index of Vertical Integration
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Price-cost margin	0.358	0.343	0.325	0.356	0.302	0.378	0.355
	(0.029)***	(0.029)***	(0.037)***	(0.029)***	(0.047)***	(0.026)***	(0.036)***
Effect of institutional measure	-0.111	-0.080	-0.044	-0.108	-0.050	-0.108	-0.053
	(0.034)***	(0.032)**	(0.039)	(0.034)***	(0.059)	(0.032)***	(0.039)
Effect of market concentration	-0.008	-0.007	0.064	-0.008	-0.108	-0.088	0.042
	(0.002)***	(0.002)***	(0.007)***	(0.002)***	(0.024)***	(0.013)***	(0.005)***
Effect of import penetration	0.504	0.491	0.170	0.413	0.474	0.325	0.235
	(0.060)***	(0.059)***	(0.066)**	(0.061)***	(0.061)***	(0.063)***	(0.063)***
Year * Country Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.416	0.416	0.428	0.416	0.389	0.419	0.428
Observations	5273	5273	5273	5273	4978	5273	5273

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. GDP is included and the main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The validity of the regression model is confirmed by the F-test in all specifications. Variables of institutional measures are described in Data Appendix.

Table 6. The role of firm ownership status for price-cost margins

	Firm Bundling of Transmission and Distribution		Majority Private		Majority Foreign	
	Roeger (1)	Variable Capital (2)	Roeger (3)	Variable Capital (4)	Roeger (5)	Variable Capital (6)
Price-cost margin	0.498	0.442	0.437	0.367	0.484	0.340
	(0.041)***	(0.035)***	(0.054)***	(0.073)***	(0.056)***	(0.072)***
Effect of market concentration	0.261	0.382	-0.362	0.741	-1.245	0.664
	(0.081)***	(0.069)***	(0.165)**	(0.106)***	(0.376)***	(0.100)***
Effect of import penetration	-0.254	-0.182	0.652	-0.105	0.557	-0.092
	(0.044)***	(0.036)***	(0.140)***	(0.078)	(0.131)***	(0.078)
Effect of bundling * HHI	0.376	0.132	---	---	---	---
	(0.094)***	(0.077)*				
Effect of private * HHI	---	---	-0.218	-0.267	---	---
			(0.080)***	(0.125)**		
Effect of foreign * HHI	---	---	---	---	-0.283	-0.739
					(0.082)***	(0.282)***
Year * Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.621	0.420	0.572	0.388	0.575	0.389
Observations	5273	5273	2187	2187	2187	2187

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. GDP is included and the main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The validity of the regression model is confirmed by the F-test in all specifications. Variables of institutional measures are described in Data Appendix.

Table 7. Estimation results regarding firm heterogeneity (Baseline Roeger model)

	All firms (1)	Diversified firms (2)	Specialized firms (3)	SME [1<emp<250] (4)	Large firms [emp>250] (5)	Firms with subsidiaries (6)	Firms with no subsidiaries (7)
Price-cost margin							
Price-cost margin [1995-2007]	0.445	0.450	0.495	0.451	0.389	0.740	0.424
	(0.023)***	(0.024)***	(0.068)***	(0.024)***	(0.070)***	(0.072)***	(0.036)***
Regulatory changes							
Effect of EC directives	-0.008	-0.007	-0.017	-0.007	-0.021	-0.025	-0.005
[No. of years since EC directive * markup]	(0.003)***	(0.003)**	(0.007)**	(0.003)**	(0.009)**	(0.006)***	(0.004)
Effect of market concentration	0.446	0.583	0.379	0.461	0.112	0.536	0.439
	(0.071)***	(0.091)***	(0.132)***	(0.076)***	(0.181)	(0.173)***	(0.099)***
Effect of trade arbitrage	-0.245	-0.260	-0.359	-0.252	-0.142	-0.777	-0.187
	(0.035)***	(0.037)***	(0.115)***	(0.037)***	(0.112)	(0.102)***	(0.054)***
Operating Authority	-0.010	-0.042	-0.038	-0.006	-0.015	0.024	0.000
	(0.003)***	(0.020)**	(0.007)***	(0.003)**	(0.008)**	(0.005)***	(0.004)
OECD Index of Regulatory Constraints	0.066	0.005	0.125	0.057	-0.087	0.080	0.070
	(0.008)***	(0.012)	(0.013)***	(0.009)***	(0.028)***	(0.019)***	(0.011)***
Organized Market Exchange	-0.007	0.001	-0.043	-0.007	0.010	-0.001	-0.014
	(0.002)***	(0.003)	(0.006)***	(0.003)**	(0.006)*	(0.005)	(0.003)***
Retail Market Opening	-0.070	-0.013	-0.045	-0.025	-0.045	-0.025	-0.026
	(0.016)***	(0.004)***	(0.005)***	(0.003)***	(0.008)***	(0.007)***	(0.004)***
Observations	5273	1246	4027	4738	535	916	2861

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. GDP is included and the main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The validity of the regression model is confirmed by the F-test in all specifications. Variables of institutional measures are described in Data Appendix.

Table 8. Estimation results regarding different types of electricity generators (Roeger model)

	Nuclear (1)	Oil-fired (2)	Gas-fired (3)	Coal-fired (4)	Hydro (5)	Wind (6)	Renewable (7)
Price-cost margin	0.571	0.326	0.359	0.427	0.385	0.341	0.413
	(0.334)*	(0.046)***	(0.047)***	(0.050)***	(0.104)***	(0.046)***	(0.105)***
Effect of generator availability	0.381	0.044	0.245	-0.726	-0.058	-1.019	-0.001
	(0.117)***	(0.167)	(0.083)***	(0.138)***	(0.088)	(0.378)***	(0.001)
Effect of market concentration	-0.170	0.293	0.272	0.107	0.326	0.205	0.321
	(0.173)	(0.102)***	(0.081)***	(0.089)	(0.085)***	(0.089)**	(0.082)***
Effect of trade arbitrage	-0.356	-0.056	-0.150	0.128	-0.117	0.005	-0.141
	(0.358)	(0.053)	(0.059)**	(0.059)**	(0.112)	(0.052)	(0.108)
Year * Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	3018	4001	4001	4001	4002	4002	4002
R-squared	0.593	0.653	0.654	0.656	0.653	0.654	0.653

Notes: Standard errors are in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. FE robust refers to results with the standard errors from the fixed-effects regression corrected for serial correlation and heteroskedasticity. OLS robust refers to a robust ordinary-least squared estimator with the standard errors from the fixed-effects regression corrected for serial correlation and heteroskedasticity. The main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity.

Table 9. Other robustness checks

	Sample with balanced data			**Sample without Nord Pool**		
	Roeger (1)	Var. Capital (2)	Roeger (CRS) (3)	Roeger (4)	Var. Capital (5)	Roeger (CRS) (6)
Price-cost margin	0.448	0.376	0.503	0.605	0.449	0.682
	(0.025)***	(0.022)***	(0.024)***	(0.067)***	(0.053)***	(0.063)***
Effect of market concentration	0.495	0.367	0.492	0.428	0.392	0.422
	(0.087)***	(0.074)***	(0.083)***	(0.070)***	(0.055)***	(0.066)***
Effect of trade arbitrage	-0.202	-0.121	-0.166	-0.431	-0.250	-0.426
	(0.040)***	(0.035)***	(0.038)***	(0.089)***	(0.070)***	(0.085)***
GDP	0.027	-0.009	0.014	-0.026	-0.007	-0.075
	(0.057)	(0.004)**	(0.054)	(0.040)	(0.003)**	(0.180)
Year * Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.563	0.415	0.650	0.608	0.401	0.694
Observations	3405	3405	3405	4405	4405	4405

Notes: Robust standard errors from the fixed-effects and ordinary-least squared regressions are corrected for serial correlation and heteroskedasticity and reported in brackets; ***,**,* denote respectively statistical significance at 1%, 5% and 10%. The main effects of the variables used to compute the interaction terms are included to exclude the possibility that main effects and interaction effects are confounded, but are not displayed for brevity. The sample with balanced data includes only firms for which the data are available for the whole time span. The sample without Nord Pool excludes the firms from Nordic countries. The effect of competition from nuclear plants is measured by an interaction term of price-cost margins times the share of nuclear output of electricity in a country's total output of electricity generated from all sources for countries with nuclear plants.