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A Joint Estimation of Price-Cost Margins and Sunk Capital

- Theory and Evidence from the European Electricity Industry

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A Joint Estimation of Price-Cost Margins and Sunk Capital:

Theory and Evidence from the European Electricity Industry[1]

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Abstract

In this paper, we propose a new methodology to jointly estimate market power and the importance of sunk capital extending the work of Hall (1988) and Roeger (1995). We then apply this new technique to the European electricity industry using firm level data for the period 1994-1999, and analyze the impact of the 1996 European directive to liberalize electricity markets. We find that the average price cost margin has declined from 0.29 in 1994 to 0.22 in 1999. Moreover, the magnitude of the decline is linked to firm size: the largest firms have experienced a larger percentage fall. The variable cost parameter has increased from 0.36 in 1994 to 0.56 in 1999. The main reason of the change is the switch of the relationship between real labor productivity and the share of variable capital. Our results therefore document a more competitive electricity market and a more flexible and more efficient use of capital.

Keywords: market power, fixed capital, liberalization, electricity market

JEL codes: D24, D40, L94

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1. Introduction

Following the seminal work by Hall (1986, 1988), a literature has emerged that aims at estimating the markup of price over marginal cost. This method is based on the simple idea that the Solow residual only provides an unbiased measure of total factor productivity (TFP) growth under the assumption of perfect competition. The bias due to imperfect competition can be shown to be proportional to the markup, allowing therefore its estimation. However, the method has been criticized for yielding high estimates. In this paper, we argue that these high estimates can partly be explained by the presence of fixed capital. We provide a new methodology that jointly estimates the markup and the importance of fixed capital. We then apply our technique to a firm-level dataset from the European electricity industry.

Studying the evolution of the markup and the lack of capital flexibility is particularly relevant for the European electricity industry. On the one hand, bringing more competition is the main motivation behind the creation of a single market for electricity advocated by the European Commission. On the other hand, recent technological advancements have permitted the adoption of more flexible production technologies. We would therefore expect markups to decline and capital to become more flexible. Our paper tests these two assumptions. It also stresses the importance of controlling for fixed capital to provide an economic interpretation of the size of markups.

The intuition of our methodology is the following: (1) both the primal and the dual Solow residuals with input shares weighted by revenue mismeasure TFP growth in the presence of market power and the bias inflicted is proportional to the markup, which can then be estimated (Roeger, 1995); (2) primal and dual Solow residuals with cost (instead of revenue) weights are unaffected by the presence of markups (Hall, 1990) but only measure TFP growth correctly in the absence of fixed capital. The bias in TFP growth measurement is proportional to the share of fixed capital and this allows us to estimate it. Combining these two ideas forms the core of our analysis.

Our methodology differs from the (recent) usual practice in the estimation of market power in the electricity sector. Following Joskow and Schmalensee (1983), Wolfram (1999) argues that, because the production technology in the electricity sector is straightforward and well understood, marginal costs can be directly computed on the basis of the cost of fuel (specific to the type of plant) and the efficiency of transformation. She applies this technique to the new electricity market in England and Wales during 18 months between 1992 and 1994. She then compares prices to marginal cost and finds highly variable estimates of the Lerner index between 0.19 and 0.24, She also finds that the link between the Lerner index and quantities supplied increased after March 1994. Borenstein, Bushnell and Wolak (2002) follow a similar procedure but estimate price in an efficient perfectly competitive market. They then measure the extent of market power in the California electricity market before and during the crisis of summer 2000 by comparing actual and estimated prices. They find significant departure from competitive pricing during the summer months when demand is high and an increase in the Lerner index. They conclude that 59% of the four-fold electricity expenditures increase between the summer 1999 and the summer 2000 can be attributed to market power. We provide an alternative way to estimate the Lerner index maintaining the hypothesis that marginal cost is unobservable and using public data that are easy to obtain. The dataset that we use provides yearly firm (and not plant) level data. This contrasts with the data available in the other studies mentioned: e.g. Wolfram used bids submitted every 30 minutes on the English & Wales electricity market. However, we are not able to consider the timing of market power along the day and with demand along the year. Rather we estimate an average Lerner index for a given year.

We find that the price cost margin (PCM) declined by 13% from 0.29 in 1994 to 0.22 in 1999. More importantly, this reduction has been exercised mostly by a change in the relationship between size and the PCM. Moreover, we find that the share of fixed costs in capital has diminished considerably after 1996, what might indicate that firms have more flexibility and make a better use of their existing capital. This evolution can be linked to technological change, unbundling of generation and transmission or to a strategy of reorganization of the capital stock leading to a reduction of fixed costs. The level of our estimates is comparable to the figures obtained in other studies (see e.g. Wolfram, 1999). While the PCM decrease can be interpreted as a sign of increased competition, the levels remain high, especially for the largest firms in countries that liberalized the electricity market more recently. In view of the existing evidence from countries where liberalization is more advanced, our paper would tend to advocate prudence in the way liberalization takes place and the European electricity market architecture is designed.

The paper is organized as follows. Section 2 presents our empirical methodology. Section 3 describes the firm level dataset that we use for the estimation. Section 4 discusses the results and section 5 concludes.

2. Methodology

We assume that electricity production can be modeled within the neoclassical production framework, i. e. the technology of firm *i* in year *t* can be described as:

$$(1) \qquad Q_{it} = \Theta_{it} F\left(K_{it} - K_{it}^{S}, M_{it}, N_{it}\right) = \Theta_{it} F\left(K_{it}^{V}, M_{it}, N_{it}\right)$$

where output Q is produced with labor N, materials M and capital K, and where a certain fraction of the total capital stock is sunk (K^s) [4]. *F(.)* is homogeneous of degree 1 in variable capital K^V, materials and labor. With this specification, declining costs are generated by the presence of fixed capital. K^S is defined here as the type of capital which is not adjusted within a period to current period demand and cost conditions, while K^V is the fraction of total capital which is adjusted to demand and cost conditions in the current period without friction. Data availability precludes an unambiguous distinction between the two types of capital. As will be shown below,

[4] To keep notation simple, we omit firm and time subscripts in the derivations.

however, we will be able to estimate the share of fixed capital by fully exploiting the implications of the production model.

Corresponding to the production function, there exists a variable cost function:

$$(2) \qquad C(W, R, Q, \Theta) = \frac{G(W, R)Q}{\Theta}$$

Under imperfect competition, firms set prices as a markup ($\mu = \frac{p}{c} = \frac{1}{1-\beta}$) over marginal cost, where β is the price cost margin or Lerner index ($\beta = \frac{p-c}{p}$):

$$(3) \qquad P = \frac{1}{1-\beta} MC$$

For estimation, we postulate a simple markup model by allowing price cost margins to vary systematically with firm size. We allow for a term v to capture unobserved heterogeneity.

$$(4) \qquad \beta_i = \beta_0 + \beta_1 Q_i + v_i .$$

The share of fixed capital is also firm specific and can vary systematically with the level of economic activity of a given firm over time as well as with respect to firm size over the cross sectional dimension. Unfortunately this share is not directly observable and we need to find an approximation for s. We use labor productivity as a proxy for s. We show in Appendix A that this can be derived endogenously under various assumptions regarding the technology. As s is bounded between 0 and 1, we assume a logistic function to describe the relationship between s and Q/N:

(5) $$s\left(\frac{Q}{N}\right)=\frac{1}{1+\exp(s_0+s_1 Q/N+u)}$$

where u is an error term.

In the following, we show how cost and revenue based Solow residuals are affected by the presence of markups ($\mu>1$ or $\beta>0$) and fixed costs (s<1). This forms the basis for our estimation.

2.1 Interpreting Solow residuals with imperfect competition and sunk capital

Consistent measurement of individual factor contributions to output and prices under alternative market structures requires consistent measurements of marginal products. Since marginal products cannot be observed directly, one can make use of first order conditions from profit maximization. However, real factor prices can be used directly only under perfect competition. Generally, factor prices underestimate the true marginal product proportionally to the markup of prices over marginal cost. As shown by Hall, this factor can be extracted from conventionally measured Solow residuals. The FOCs form the basis for our analysis, they are given by

(6a) $$\Theta F_N=\mu\frac{W}{P}=\frac{W}{P(1-\beta)}$$

(6b) $$\Theta F_M=\mu\frac{P_M}{P}=\frac{P_M}{P(1-\beta)}$$

(6c) $$\Theta F_{K^V}=\mu\frac{R}{P}=\frac{R}{P(1-\beta)}$$

where W is the price of labor, P_M is the price of materials and R is the price of capital.

First, we show the bias inflicted on Solow residuals with factor contributions weighted by their respective revenue shares. In a second step, we discuss another weighting scheme, namely cost weights, and show that these measures are ideally suited for extracting the share of fixed capital.

2.2 Primal and Dual Solow Residuals with Revenue Shares

Logarithmic differentiation of the production function (1) and using the FOC's (6a-c) together with Euler's law allows us to write the change of output as a weighted average of the change in inputs plus technological progress as follows[5]

(7) $$\Delta q = \frac{RK^V}{(1-\beta)PQ}\Delta k^V + \frac{WN}{(1-\beta)PQ}\Delta n + \frac{P^M M}{(1-\beta)PQ}\Delta m + \Delta\theta$$

Note that, under imperfect competition, the output contribution of individual production factors exceeds their respective revenue shares by the term 1/(1-β).

Similarly, logarithmic differentiation of marginal cost and using Shepard's lemma allows us to write the change of prices as a weighted average of factor prices minus the rate of technical progress. The factor price weights are again the factor shares adjusted for 1/(1-β).

(8) $$\Delta p = \frac{RK^V}{(1-\beta)PQ}\Delta r + \frac{WN}{(1-\beta)PQ}\Delta w + \frac{P^M M}{(1-\beta)PQ}\Delta p^M - \Delta\theta$$

Using these relationships, we can define the primal and dual Solow residuals and see how they are related to TFP and a markup component. There is, however, one complication, namely the unobservability of K^v and its annual growth rate. The factor share of variable capital does not pose a problem since, under our technological assumptions, it can be represented as

[5] We use the following notation: Δx denotes the log difference of the variable *X*.

(9) $$\frac{RK^{V}}{PQ} = (1-\beta) - \frac{WN}{PQ} - \frac{P^{M}M}{PQ}$$

Using Eq. (5), we can write growth rate of variable capital as follows:

(10) $$\Delta k^{v} = \varepsilon_{sx}\Delta x + \Delta k$$

where x is labor productivity and $\varepsilon_{sx} = \frac{ds}{dx}\frac{x}{s}$ is the elasticity of the variable capital share with respect to labor productivity.

Denote the revenue weighted primal and dual Solow residuals as SRQ^{R} and SRP^{R} respectively:

(11) $$SRQ^{R} = \Delta q - (1 - \frac{WN}{PQ} - \frac{P_{M}M}{PQ})\Delta k - \frac{WN}{PQ}\Delta n - \frac{P^{M}M}{PQ}\Delta m$$

(12) $$SRP^{R} = (1 - \frac{WN}{PQ} - \frac{P_{M}M}{PQ})\Delta r + \frac{WN}{PQ}\Delta w + \frac{P^{M}M}{PQ}\Delta p^{M} - \Delta p\,.$$

Using (7) and (8), these two productivity measures can be written as weighted averages of true TFP and a markup plus a fixed capital component:

(13) $$SRQ^{R} = \beta(\Delta q - \Delta k) + (1 - \beta - \frac{WN}{PQ} - \frac{P^{M}M}{PQ})\varepsilon_{sx}(x)\Delta x + (1-\beta)\Delta\theta$$

(14) $$SRP^{R} = -\beta(\Delta p - \Delta r) + (1-\beta)\Delta\theta$$

Both residuals are functions of the markup level but not the level of fixed costs. The dual Solow residual is unaffected by fixed costs and the primal measure only responds to changes in *s*.

2.3 Primal and Dual Solow Residuals with Cost-Based Shares

The use of cost weighted TFP measures was suggested by Hall (1990) as a way of avoiding the bias inflicted by imperfect competition on the measurement of the rate of technical progress. In this section, we show that these alternative measures are indeed fairly robust with respect to the presence of imperfect competition. However, they turn out to be more sensitive to the presence of fixed costs in a fashion which can be exploited for extracting s from cost weighted Solow residuals. Since, under constant returns to scale, we have:

$$(15) \qquad (1-\beta)PQ = (MC)Q = C^V = RK^V + WN + P_M M \, .$$

We can simply rewrite Eq. (7) and (8) with variable cost shares:

$$(7') \qquad \Delta q = \frac{RK^V}{C^V}\Delta k^V + \frac{WN}{C^V}\Delta n + \frac{P^M M}{C^V}\Delta m + \Delta\theta$$

$$(8') \qquad \Delta p = \frac{RK^V}{C^V}\Delta r + \frac{WN}{C^V}\Delta w + \frac{P^M M}{C^V}\Delta p^M - \Delta\theta$$

From (7′) and (8′), we notice that the presence of fixed costs creates a similar measurement problem as the presence of markups for the measurement of revenue weighted Solow residuals. Ideally, the contribution of factors and their prices to output and output prices should be weighted with their respective shares in variable costs. Like in the case above - where we do not observe revenue minus profits - we do not observe total cost less fixed costs.

Therefore, conventionally measured cost weighted Solow residuals (SRQ^C and SRP^C), which use total cost weights

(16) $$SRQ^{C} = \Delta q - \frac{RK}{C}\Delta k - \frac{WN}{C}\Delta n - \frac{P^{M}M}{C}\Delta m$$

(17) $$SRP^{C} = \frac{RK}{C}\Delta r + \frac{WN}{C}\Delta w + \frac{P^{M}M}{C}\Delta p^{M} - \Delta p$$

will also inflict a bias which is proportional to the share of fixed capital. To see this, simply use the definition of variable cost

(18) $$C^{V} = C - \left(1-s\right)RK = RK - \left(1-s\right)RK + WN + P_{M}M \ .$$

Substituting this expression into (16) and (17) allows us after some simple manipulations to represent the two cost weighted TFP measures as follows:

(19) $$SRQ^{C} = (1-s(x))\frac{RK}{C}(\Delta q - \Delta k) + s\frac{RK}{C}\varepsilon_{sx}(x)\Delta x + \frac{C^{V}}{C}\Delta\theta$$

(20) $$SRP^{R} = -(1-s(x))\frac{RK}{C}(\Delta p - \Delta r) + \frac{C^{V}}{C}\Delta\theta \ .$$

As can be seen from (19) and (20), both residuals are ideal measures for the rate of technical progress only in the absence of sunk capital. In the presence of sunk capital, both measures would indicate a positive rate of technical progress also in situations where output rises more strongly than total capital and fall in prices exceeds the fall in capital cost. This is intuitively plausible. Assume a firm only produces with a fixed capital share equal to one. In this case, the primal residual would be biased upward with an output expansion generated entirely by an increase in variable inputs, because the contribution of labor and materials to changes in output are underestimated and, therefore, a part of the output change is wrongly attributed to the technology residual. Similarly, there are circumstances in which the dual residual would indicate technical progress when in fact there is none. Assume, for example, an increase in capital cost. With marginal cost pricing, this would not affect output prices and therefore the dual residual would wrongly attribute the increase in real capital cost to the technology residual.

2.4 Identifying the size of markups and the share of fixed capital

The four Solow residuals as represented by equations (13), (14), (19) and (20) provide information about sunk costs and markups. The econometric problem consists in estimating *s* and β, and control for changes in technology. This is a problem since the regressors are likely to be correlated with the technology term. A comparison of the primal and dual residuals shows that the technology term can be eliminated altogether by simply subtracting the corresponding primal and dual residuals from each other:

$$(19)\ SRQ_{it}^{R} - SRP_{it}^{R} = \beta_{it}\left[(\Delta q_{it} + \Delta p_{it}) - (\Delta k_{it} + \Delta r_{it})\right] + (1 - \beta_{it} - \frac{W_{it}N_{it}}{P_{it}Q_{it}} - \frac{P_{it}^{M}M_{it}}{P_{it}Q_{it}})\varepsilon_{sx}(x_{it})\Delta x_{it}$$

$$(20)\ SRQ_{it}^{C} - SRP_{it}^{C} = \left[1 - s(x_{it})\right]\frac{R_{it}K_{it}}{C_{it}}\left[(\Delta q_{it} + \Delta p_{it}) - (\Delta k_{it} + \Delta r_{it})\right] + \frac{R_{it}K_{it}}{C_{it}}s(x_{it})\varepsilon_{sx}(x_{it})\Delta x_{it}$$

It follows from these expressions that the primal and dual residuals are systematically related to the change in nominal output relative to the value of capital services. The difference is roughly proportional to the size of the markup in the case of revenue weights and to the share of fixed capital in the case of cost weights. Only under perfect competition and fully flexible adjustment of capital would both sets of primal and dual residuals be identical. These two equations can be estimated consistently provided the measurement errors are uncorrelated with the nominal capital output ratio. Roeger (1995) provides a discussion of the measurement error issue. Here additional measurement errors arise because β may have a stochastic component and *s* can be measured with error as discussed above. We regard the bias inflicted by these additional measurement errors as small. In the case of β we control for output variations along the time dimension by allowing markups to vary with output. Stochastic variations of β along the cross section can only cause a bias to the extent in which "level differences" in β across individual firms would be correlated with the "growth rate" in their respective nominal capital output ratios. There is no reason to expect such a relationship. A similar argument applies to the error in measuring the variable capital share. Comparing the two relationships also shows that some cross equation restrictions hold between the two equations because the change in the fixed capital share also enters the revenue based TFP difference. Therefore it is useful to estimate both relationships jointly as a system of two non linear equations with the four parameters to be estimated: β_0, β_1, s_0 and s_1. Our test concerning the economic impact of the liberalization of the electricity market in European countries consists in estimating Eq. (19) and (20) over the sub-periods: 1994-1996 and 1997-1999. We consider 1996 as the last year before deregulation came into effect.

3. Data

Our dataset provides financial information on the 500 largest firms active in the electricity sector in Europe and is extracted from *Amadeus*. The data reported included operating revenue, cost of employees, cost of materials, capital, depreciation and employment. By definition, we have more observations in countries that have opened to competition or that have allowed existence of several firms on the market historically. The bulk of our sample is therefore composed of German firms; we also have a reasonable amount of firms from Austria, Spain and Finland, but a very limited amount of firms from France, Belgium and Italy. The quality of the data for the other countries did not allow us to include them in our analysis.

We selected all firms involved in the 3-digit NACE Rev. 1 industry 401 "production and distribution of electricity". The raw data did not allow us to make a difference between firms present in the distribution sector and those involved in generation. However, we looked one by one to exclude firms not present in generation.

We have also cleaned the data to make sure that we have comparable firms. We only consider observations where the share of material costs and the share of wages in turnover is larger than 0.01 and smaller than 1, and when the absolute value of nominal growth of output and input is smaller or equal than 0.6 (this means that we ruled out large mergers in the first year of their operation). We end up with a sample of 165 firms providing 570 observations, an average of 3.45 observations per firm. Table 1 provides the summary statistics.

Table 1: Summary statistics

Variable	mean	Std. dev.
Output (in millions 1995 Euros)	790.5	2569
Employment	2,397	11,139
α_N	0.16	0.08
α_M	0.53	0.14
δ	0.07	0.03
$\Delta\log(PQ)$	0.0003	0.01
$\Delta\log P_M M$	-0.025	0.138
$\Delta\log WN$	0.0097	0.11

4. Results

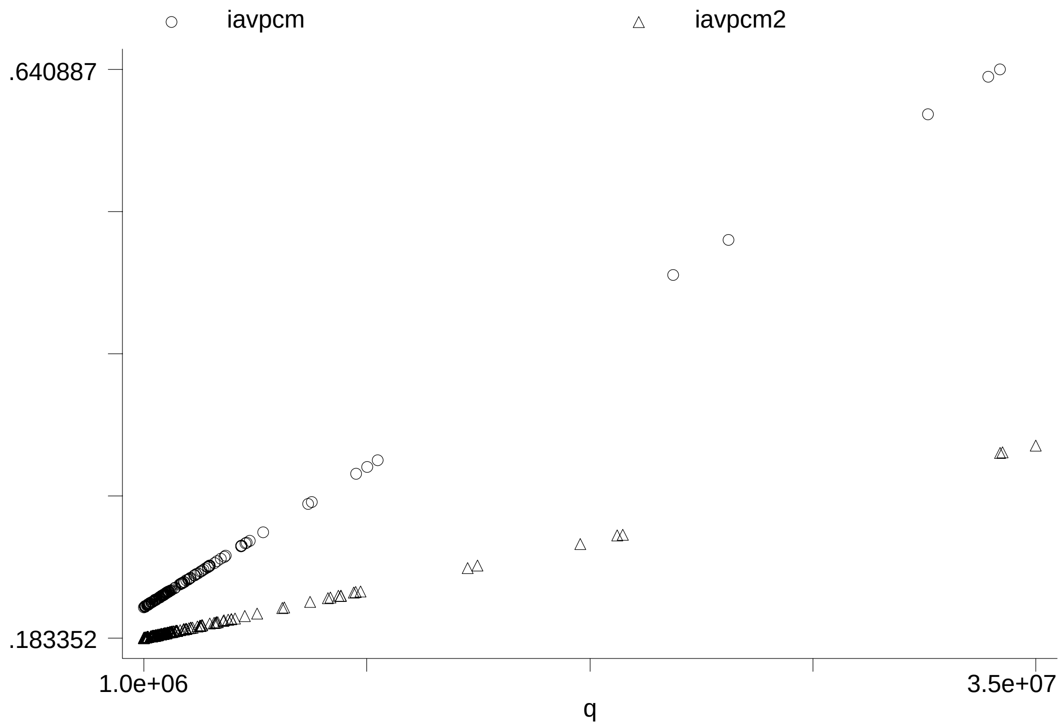
Table 2 provides the results of the estimation of our system of non linear equations (19) and (20). We find evidence of substantial heterogeneity in the price cost margins and in the share of variable costs. Price cost margins increase with the size of the firm, and the share of variable capital is positively linked to real labor productivity.

Table 2: results

	1994-1996	**1997-1999**
β_0	0.195^{**} (0.008)	0.179^{**} (0.007)
β_1	$1.31*10^{-8\,**}$ $(3.3*10^{-9})$	$4.5*10^{-9}$ $(3.9*10^{-9})$
s_0	8.360^{**} (0.711)	2.252^{**} (0.475)
s_1	1.361^{**} (0.124)	0.448^{**} (0.080)

Note: standard errors in parentheses; ** indicates statistical significance at the 5% critical level

Figure 1: the change in the relationship between price cost margins and size



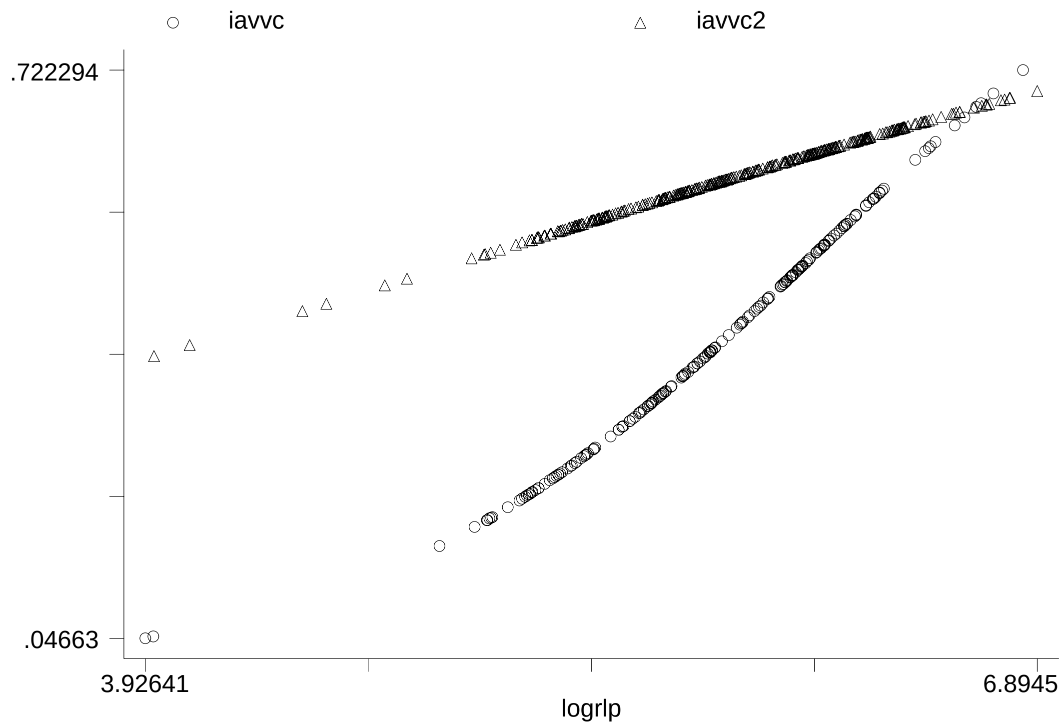
Note: iavpcm=individual average price cost margin for the period 1994-1996;
iavpcm2=individual average price cost margin for the period 1997-1999

The evolution of our parameters is interesting to note. The (quantity weighted) average price cost margin has declined from 0.29 in 1994 to 0.22 in 1999. However, the magnitude of the decline is linked to the size of the firm: the largest firms have suffered from a larger percentage fall. Figure 1 shows the switch in the PCM-size relationship.

One way to interpret this decline is that incumbents have faced market share losses as competition at the national level has increased. Moreover, there has been a decline in the constant component of the PCM, reinforcing the previous effect.

On the other hand, the (quantity weighted) average variable cost parameter has increased from 0.36 in 1994 to 0.56 in 1999. Again, the main reason of the change is the switch of the relationship between real labor productivity and the share of variable capital. Figure 2 shows that there has been an upward switch, especially for low and medium-productivity firms, while high productivity firms have hardly made any change. This suggests that firms with average or low productivity have adopted more flexible production structure.

Figure 2: The change in the variable capital parameter



Note: iavvc=individual average share of variable cost for the period 1994-1996;
iavvc2=individual average share of variable cost for the period 1997-1999

Altogether, our findings indicate a dramatic transformation of the European electricity industry. Pricing has become more competitive and, in particular, PCMs have become less sensitive to the size of the firm. At the same time, the share of fixed capital has diminished, what can be interpreted in various ways. First, technological change and regulatory change have allowed entry of new plants with less fixed capital. Second, unbundling has freed resources for generation. Third, firms have restructured and adopted more flexible production techniques. We are unable to determine the exact proportion that can be attributed to liberalization, but, in any case, this paper documents a positive evolution of the industry.

Our results are robust when we allow the PCM to have a country specific component to capture potential differences in the regulatory regime. There was no significant effect.

We do a further robustness check by observing that under the two extreme opposite assumptions of perfectly fixed capital and full capital adjustment within the period of observation, the markup can be estimated on the basis of the revenue weighted Solow residual only. Though this assumption is likely to inflict a bias for the markup estimate, it nevertheless seems to be a useful exercise if one is interested in the change of the markup after liberalization since one would not expect the liberalization to affect the size of the bias and we therefore expect to obtain a lower estimate in the second period. As can be seen from Table 3 we obtain a reduction in the same order of magnitude.

Table 3: results

	1994-1996	**1997-1999**
β_0	0.326^{**} (0.014)	0.304^{**} (0.012)
β_1	$1.54 * 10^{-8\,**}$ $(9.8 * 10^{-9})$	$-4.0 * 10^{-9}$ $(8.8 * 10^{-9})$

Note: standard errors in parentheses; ** indicates statistical significance at the 5% critical level

Note also that the level of markups is substantially higher if we do not control for capital fixity. This is consistent with our previous hypothesis that the capital cost can partly be adjusted to current economic conditions, since in this case we expect the output coefficient (inverse of the capital output ratio) to be positively correlated with productivity.

6. Conclusion

In this paper, we have developed a new methodology to jointly estimate market power and the importance of sunk capital extending the work of Hall (1988) and Roeger (1995). The analysis is based on the simple idea that we can exploit the properties of the cost share weighted and the revenue share weighted Solow residuals, which are affected differently by the presence of fixed capital and imperfect competition.

We have applied our methodology to the European electricity industry using firm level data for the period 1994-1999, and analyzed the impact of the 1996 European directive to liberalize electricity markets. As predicted by our theoretical model, the differences between the two sets of Solow residuals are systematically related to indicators of markups and of fixed capital.

We find that the average price cost margin has declined from 0.29 in 1994 to 0.22 in 1999. Moreover, the magnitude of the decline is linked to firm size: the largest firms have experienced a larger percentage fall. On the other hand, the variable cost parameter has increased from 0.36 in 1994 to 0.56 in 1999. The main reason of the change is the switch of the relationship between real labor productivity and the share of variable capital. Our results therefore document a more competitive electricity market and a more flexible and more efficient use of capital.

References

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

Hall, R.E., 1986. Market Structure and Macroeconomic Fluctuations. Brookings Papers on Economic Activity 2, 285-322.

Hall, R. E., 1988. The Relation between Price and Marginal Cost in U.S. Industry. Journal of Political Economy 96 (5), 921-947.

Hall, R. E., 1990. Invariance Properties of Solow's Productivity Residual, in Diamond, P. (ed.), Growth, productivity, Unemployment: Essays to celebrate Bob Solow's Birthday, Cambridge, MA: MIT Press, 71-112.

Roeger, W., 1995. Can Imperfect Competition Explain the Difference between Primal and Dual Productivity Measures? Estimates for U.S. Manufacturing. Journal of Political Economy 103(2), 316-330.

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

Appendix A

To facilitate this discussion we look at a specific Leontieff technology:

$Y_{it} = \min(a_i N_{it}, b_i K_{it}^v) - K_{it}^s$ [6].

Along the time series dimension we ask the question: how do variations of *Q* over time affect *s* and Q/*N* for given technological parameters $\left(a, b, K^S\right)$. Since K^v and *N* are used in fixed proportions, we obtain the following expression for average labor productivity

$$\frac{Q}{N} = a - \frac{a}{b}\frac{K^s}{K^v} = a - \frac{a}{b}\left(\frac{1}{s} - 1\right)$$

which shows that along the time series dimension there is a positive relation between labor productivity and the share of fixed capital. At the cross sectional dimension we have to take into account that because of (country) specific market conditions, regulations and transport costs different technologies coexist, i. e. *a*, *b*, and K^s vary over individual firms. Assume there exists a high and low fixed cost technology T_i, $i = h, l$, which can be characterized by the triple $T_i = (a_i, b_i, K_i^s)$, with $K_h^s > K_l^s$. For T_h to be cost minimizing at some level of output it must be the case $N(a_h, b_h) > N(a_l, b_l)$ must hold, where *N(.)* is some norm of the vector (*a,b*). In other words, T_h has higher fixed costs but lower variable costs. It follows immediately that there exists a level of output Q* such that total cost of T_l are smaller for $Q < Q^*$ and larger for $Q > Q^*$. Suppose both technologies are operated in some market. For T_l, we know that the maximum level of labor productivity is given by:

$$\max\left(\frac{Q_l}{N_l}\right) = a_l - \frac{K^s}{a_l(Q^* + K^s)}$$

and maximum ratio of variable to fixed capital (which is a positive function of s) is given by

$$\max\left(\frac{K_l^v}{K_l^s}\right)=\frac{a_l^{\,2}(Q^*+K_l^s)}{b_l K_l^s}.$$

Since both, labor productivity and the variable capital share are increasing functions of output, it follows that there exists a level of output Q**>*Q** such that

$$\left(\max\left(\frac{Q_l}{N_l}\right),\max(s_l)\right)<\left(\frac{Q^{**}}{N_h},s_h\right)$$

Notice, this inequality only holds for sufficiently large levels of output (*Q***), depending on the production parameters *a* and *b*. Therefore across the cross sectional dimension the relationship between labor productivity and a variable capital share only holds with an error.

[6] With more general technologies changes in relative factor prices could be an additional factor affecting the capital share. In this paper we ignore this effect.

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