Effects of the Opening of the Energy Markets on the Cost Efficiency of the Big European Players

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Abstract

The aim of the work is to examine the potential impact of liberalization on the cost of the main energy firms in Europe. The literature on the link between competition and market liberalization is large and still growing in Europe. Liberalization, such as the removal of entry barriers, or the abolition of state monopolies, is usually associated to larger competition among firms. On the contrary theoretical and empirical findings on the effects of a more competitive environment on firms' performance are less clear cut. To the best of our knowledge there are no studies that consider the effect of liberalization, where all customers will be able to choose their energy (electricity and/or gas) supplier, on firms' efficiency. We consider the estimation of a stochastic frontier cost function for a panel dataset, covering 20 among the largest European energy companies observed over the period 2000-2009. We simultaneously estimate the cost function and the inefficiency model, i.e. a linear specification that includes a set of environmental or external factors as explanatory variables of the mean of the pre-truncated normal distribution of the inefficiency term. The main explanatory variables for the mean inefficiency term is a set of indicators for the proportion of the market actually open to competition, switching rates, the market concentration ratio. In general inefficiencies decrease when the market is open and more competitive, especially in the electricity market. On the contrary, a certain level of market concentration seems to act improving performances, especially in the gas sector.

Keywords: cost efficiency, energy companies, opening European energy market, electricity, gas
JEL: D24, L94, L95

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1. Introduction

During the last two decades the European energy industry has been involved in relevant reforms, mainly related to the Union efforts directed towards the creation of a liberalized single European energy market. The process is based on three main legislative pillars (“packages”).Starting from the 96/92/EC Directive concerning common rules oriented to improving the functioning of the internal energy market the European power sector was restructured in order to produce competition in generation and supply. The gas sector was interested by a similar process in 1998, oriented to the separation of distribution and supply. Thanks to the second EC Directive (2003/54), since July 2004, European small-business customers are free to choose their supplier for electricity and gas, while 2007 was set as the deadline for full market opening (including households). The second Directive also introduced more pervasive unbundling requirements (legal unbundling) for the network operations and imposed the appointment of competent bodies as national regulators, independent from the industry.

Finally, the third Energy package entered into force in September 2009, requiring the introduction of ownership unbundling, the setting up, for each Country, of a single regulatory Authority at national level completely independent also from the Government, and creating an Agency for the cooperation of energy regulators; customers’ protection was further enhanced. The implementation of the process towards liberalization has been slow in showing its effects. The European Commission enquiry on the agreements and abuses of dominant positions (COM 2006/851) still highlighted the impossibility for many European consumers and industrial facilities of purchasing energy from a wide number of suppliers competing within their own country or beyond the international European market. This means that, at that moment, competition is still distorted and companies and consumers were unable to take full advantage of liberalisation.

The main obstacles in this sense seemed to be high market concentration, vertical foreclosure, absence of market integration and it is important to understand which of them could be an effective target for the EU policy.

The degree of concentration remained almost the same as prior to liberalisation, with the local firms maintain a large control of generation, distribution as well as of gas imports.

Market concentration implies monopolistic power but, on the other hand, larger firms can benefit of economies of scale. In fact, while the minimum efficient size has fallen strongly in the electricity generation, at the same time a number of studies (Giles and Wyatt, 1993, Salvanes and Tjotta, 1994, Filippini, 1996) give evidence of economies of scale in the distribution segment. Yatchew (2000) confirms increasing returns to scale only for small firms and substantial economies in power procurement.

With respect to vertical foreclosure, we know that vertical integrated operators in a regulated and partially liberalised market can distort competition. They might limit supply at the generation stage in order to obtain price advantages. At the distribution stage they might charge discriminatory prices. The same firm managing the different stages of the industry gives the opportunity of cross-subsidization practices. However, the simultaneous presence of upstream and downstream stages produces cost synergies linked to lower average operations and maintenance costs, more effective coordination of the activities across the stages, savings on transaction costs. Theoretical (Polo and Scarpa, 2003) and empirical literature on vertical economies is quite wide: applied works such as Kaserman and Mayo (1991), Gilsdorf (1994), Kwoka (2002), Michaels (2004), Nemoto and Goto (2004), Fraquelli, Piacenza, Vannoni (2005) give evidence of substantial economies of vertical integration.

Paying attention to the presence of scale and scope economies, it seems that improving competition by a disintegration of the local energy industry could be a very costly measure in terms of lost production efficiency; rather we think that it would be more useful to allow all consumers to choose their supplier for energy and gas in an open and integrated European market.

Our paper addresses the above thesis by analysing the changes in efficiency at firm level after the implementation of the opening of the electricity and gas markets and the effects of competition intensity in the European countries.

We estimate a stochastic cost frontier for a sample of 20 firms among the largest European energy companies observed over the period 2000-2009. We simultaneously estimate the cost function and the inefficiency model, i.e. a linear specification that includes a set of environmental or external factors as explanatory variables of the mean of the pre-truncated normal distribution of the inefficiency term u_{it} (Wang and Ho, 2010). We test different sets of explanatory variables for the mean inefficiency term: the proportion of the market actually open to competition, switching rates, the market share of leader retailers.

Our identifying strategy is based on the impact of market liberalization on firm level efficiency (as measured by a stochastic frontier) exploiting cross-country variation in the extent and timing of policy reforms. In particular we are able to take into account unobserved firm heterogeneity by estimating a fixed effects specification

The rest of the paper is organized as follows. In section 2 we present the literature, while section 3 introduces our estimation strategy. In section 4 we discuss the sources and the characteristics of the data, and in section 5 the estimation results are interpreted while section 6 discusses some model extensions. Section 7 concludes.

2. Literature review

The liberalization reforms of the energy sector are complex processes encompassing several degrees of intervention, usually they take long time and in general they are far from being completed in most countries.

Jamasb and Pollit (2005), referring to reforms of the electricity sector, identify four main steps.

- *Restructuring* of the system, including for instance the vertical unbundling of the network segments from the competitive ones (generation and retail supply), or the horizontal splitting of the latter in order to reduce the market concentration.
- *Competition and markets,* i.e. designing and maintaining effective wholesale and retail markets, also by allowing new entries in the competitive branches.
- *Regulation*, which involves the existence of an independent regulator and the effectiveness of the regulatory activity itself, for instance through the implementation of incentive regulation.
- *Ownership,* i.e. privatization of the existing public business or the entry of private competitors, although the authors point out that this is not a necessary step, as the mechanisms aimed to foster competition can be applied also to publicly owned enterprises.

In principle, as argued in Joskow 2008, the more a reform is implemented in a "complete" way, the more it is likely to be successful. Often empirical works aimed at evaluating the impact of liberalization consider the effect of one, or few, of these key aspects on some variables of interest, such as efficiency and productivity, either partial or total (TFP), profitability, investments, prices, GDP (see Pollit, 2012, for a summary). In this work, we will focus on the impact of liberalization on efficiency performance of the big European players.

There are two main branches of studies assessing the effects of liberalization. The first one treats reform indicators as determinants of sector performance measured by aggregate variables at country level. Among the contribution developed within this approach, it is worthwhile to mention Steiner (2001). She employs a panel dataset including 18 OECD countries over the period 1986-1996 to assess the impact on efficiency and prices of some indicators on liberalization, either in generation and supply, on privatization and vertical integration. Efficiency is measured in terms of capacity utilization and distance from the optimal level of reserve margin. Unbundling of generation from transmission and private ownership appear to significantly improve both efficiency measures.

In a similar vein, Zhang et al. (2008) assess the impact of privatization, competition and regulation on the generators' performance in 36 developing countries. The performance variables refer to generating capacity, generated electricity, labour productivity and capacity utilization. These measures are all significantly affected only by the degree of competition, while privatization and regulation, not significant *per se*, show a positive impact when interacted.

Finally, a recent contribution is provided by Erdogdu (2011) over a panel of 92 countries. The author finds that the impact of reforms, ranked on a scale from 0 to 8 on the basis of the implementation of eight different steps of liberalization, is significant but limited with reference to all the considered performance metrics: capacity utilization, distance from the optimal reserve margin, network losses and net generation per employee. Liberalization is shown to slightly improve efficiency, except in the network losses regression, where it acts worsening the performance (i.e. increasing the losses level).

A second branch of studies is based on firm level data. For instance, an important contribution is provided by Fabrizio et al. (2007), showing that regulatory restructuring of the electricity industry in US positively affects the cost performance of generating firms. In particular the reform reduces the labour and the non-fuel inputs use, while the impact on fuel efficiency is more limited. Also in Hiebert (2002), applying a stochastic frontier method, the efficiency of coal generation plants appears to be positively affected by the implementation of retail competition and by private ownership. Kwoka et al. (2007), instead, concentrate on US distributors' performance, showing that vertical divestiture negatively affects efficiency, which is measured by means of Data Envelopment Analysis (DEA).

Among the most recent works involving South-American firms, Ramos-Real et al. (2009) focus on the changes in productivity of Brazilian electricity distributors, analysing a panel of firms over the period 1998-2005, characterized by sector reforms, mainly concerning privatization and the introduction of incentive regulation. The Malmquist-DEA results show an improvement in productivity, mostly driven by technical change, while the technical efficiency component impacts negatively, except at the end of the period.

A similar, although broader, approach is adopted by Pombo and Taborga (2006), analysing the effects of separation and privatization reforms in Colombia, occurred in 1994. Also in this case, the authors rely on DEA and Malmquist indexes for efficiency and productivity estimates, and the main results suggest a positive impact of the sector restructuring on productivity, mainly driven by technical change. Inefficient units, instead, worsen their performance, rather than showing an efficiency catch-up.

Focusing on studies based on European samples, an important contribution is provided by Arocena et al. (2011), who rely on data related to Spanish power firms. The authors, by means of a non-parametric frontier technique, implement a detailed decomposition of the value created by firms before and after the sector restructuring. The higher post-reform value creation is mainly driven by an increase in productivity, while the margin effect is less relevant. Also in this case, the productivity improvement appears to be mostly determined by technical change and by a more balanced output mix in terms of generation and distribution. The cost efficiency effect, instead, plays a limited role.

Finally, it is worthwhile to consider two works employing (European) cross-country data: Bena et al. (2011) and Zarnic (2010). While the former contribution's scope of analysis covers several network industries (airlines, electricity, gas, post, railways, telecom), the latter work focuses on electricity. However, both studies rely on parametric estimates of Total Factor Productivity (TFP) and are consistent in showing some productivity gains due to reforms, although Zarnic (2010) points out that they involve the firms closer to the frontier, while other firms show limited improvements. Finally, most of the productivity gains are shown to depend on within firm efficiency, rather than on reallocation effects.

A detailed survey of the effects of reforms on performance is provided by Jamasb et al. (2005).

3. Empirical analysis: methodological issues

We consider the estimation of a stochastic frontier cost function for a panel dataset:

$$C_{it} = y_{it}\, \alpha + x_{it} \beta + \varphi_i + \varepsilon_{it} \quad for\ i=1,\dots,N;\ t=1,\dots,T \tag{1}$$

$$\varepsilon_{it} = v_{it} + u_{it} \tag{2}$$

$$v_{it} \sim N(0, \sigma^2{}_v) \tag{3}$$

$$u_{it} = h_{it}(z, \delta)\, u_i^* \tag{4}$$

$$u_i^* \sim N^+(0, \sigma^2{}_u) \tag{5}$$

where C_{it} is the logarithm of the cost of production for firm i at time t, y_{it} is a $1 \times m$ vector of the output measures, x_{it} is a $1 \times k$ vector of input prices for the *ith* firm at time t. α and β are vectors of unknown parameters to be estimated. Finally φ_i is individual i's fixed unobservable effect and the error term $\varepsilon_{it} = v_{it} + u_{it}$ is split into two independently distributed random shocks' components: v_{it} are random variables assumed to be identically and independently distributed as $N(0, \sigma^2{}_v)$; while u_{it} are non-negative random variables which account for cost inefficiencies. We are going to model u_{it} following Wang and Ho (2010): it is given by the product of the non negative scaling function $h_{it}(z, \delta)$, that we are going to assume to be $h_{it}(z, \delta)=exp(z_{it}\, \delta)$ and the u_i^* term, a time invariant random variable that follows a truncated normal distribution $N^+(0, \sigma^2_u)$. u_i^* is independent of all T observations on v_{it} and both u_i^* and v_{it} are independently distributed across time and firms with respect to { y_{it} , x_{it} , z_{it} }. z_{it} is a $1 \times p$ vector of external factors entering the scaling function which may influence the efficiency of a firm, while δ is a $p \times 1$ vector of unknown parameters that are simultaneously estimated with α and β. The above model has the scaling property (see Wang and Schmidt, 2002, Alvarez et al., 2006), i.e. the shape of the distribution of inefficiency is the same for all firms, but the scale of the distribution is influenced by the factors in z_{it}.

The model is estimated via maximum likelihood after within transformation, where the sample mean of each panel is subtracted from every observation in the panel and the estimated index of technical efficiency from the cost frontier are defined as (Battese and Coelli, 1988):

$$EFF_{it} = E(exp(-u_{it}|\varepsilon_{it}))$$

Where EFF_{it} will take values between 0 (most inefficient firm) and 1 (most efficient firm).

One of the advantages of dealing with longitudinal data is the possibility to disentangle heterogeneity from inefficiency. Pitt and Lee (1981) were the first to adapt a stochastic frontier model to panel data. In particular they modelled inefficiency as a time invariant Half Normal random term ($u_i = \varphi_i \sim N^+(0, \sigma^2_u)$ in *(1)* and *(2)*). Schmidt and Sickles (1984) applied the ‘fixed effects’ estimation technique to the time invariant inefficiency term, in order to deal with correlation between error terms and frontier regressors. As pointed out by Greene (2005a, 2005b) the main drawback with this kind of approach is the potential identification problem as the inefficiency term u_i now captures both firm specific heterogeneity (φ_i) and inefficiency effects. Heterogeneity, especially in a dataset as the one considered here, may capture a set of time invariant factors that influence costs but are not under the control of the companies. These effects should not be considered as inefficiency. The true fixed effects proposed by Greene (2005a, 2005b) allows for the estimation of ‘true’ inefficiency effects as heterogeneity is removed by the inclusion of a set of individual (e.g. firm) specific dummy variables. Chen, Schmidt, and Wang (2011), Wang and Ho (2010) and Wang (2003) argue that the incidental parameter problem that affects the true fixed effects estimation (i.e. the fact that maximum likelihood estimators of the parameters may be inconsistent as the number of included parameters is a function of the sample size) may be overcome by a within transformation of the data prior to the maximum likelihood estimation. This is the approach we follow: in order to get rid of individual specific effects, all variables are transformed by subtracting the sample mean of each panel from every observation in the panel. In this way we avoid the incidental parameter, while controlling for the potential correlation among individual effects and included regressors.

The cost function we take to the data is the following:

$$TC = f(y\_gas\_sale, y\_elec\_sale, dummy\_elec\_prod, dummy\_gas\_transp, PC, PL, PG, \text{ Time Trend})$$

Where, *TC* represents yearly total operating costs while vector *y* contains the two outputs we consider, i.e. gas sale, and electricity sale, both expressed in TWh. *PC, PL,* and *PG* are input prices and they represent the prices of capital, labour, and natural gas respectively. We also include in all specifications a time *trend*, to capture technological change. We also experimented with the inclusion of two dummies for the production of electricity (*dummy_elec_prod*) and gas transportation (*dummy_gas_transp*). As with respect to the functional form, we opted for a Translog Specification:

$$\begin{aligned} ln(TC/PC) = {} & \alpha_0 + \alpha_1\, ln(y\_gas\_sale) + \alpha_2\, ln(y\_elec\_sale) + ½\, \alpha_{11}\, ln(y\_gas\_sale)^2 + ½\, \alpha_{22}\, ln(y\_elec\_sale)^2 + \alpha_3\, ln(y\_gas\_sale)\, ln(y\_elec\_sale) + \beta_1\, ln(PL/PC) + \beta_2\, ln(PG/PC) + ½\, \beta_{11}\, ln(PL/PC)^2 + ½\, \beta_{22}\, ln(PG/PC)^2 + \beta_3\, ln(PL/PC)\, ln(PG/PC) + \beta_4\, ln(PL/PC) ln(y\_gas\_sale) + \beta_5\, ln(PG/PC)\, ln(y\_gas\_sale) + \beta_6\, ln(PL/PC) ln(y\_elec\_sale) + \beta_7\, ln(PG/PC)\, ln(y\_elec\_sale) + \lambda_1\, Trend + \lambda_{11}\, Trend^2 + v + u \end{aligned} \tag{6}$$

Where, the α_j's , β_j's and λ_j's are the unknown parameters to be estimated, and *v* and *u* are the random shocks and the cost inefficiency term respectively (firm and time subscripts are omitted to simplify notation). The time invariant firm specific fixed effects φ_i are removed from the model by within transformation.

The translog specification is a flexible functional form for the cost function in order to capture the features of the frontier and it is often used in the energy cost literature (Hiebert, 2002).

In order to deal with a well-behaved cost function, homogeneous of degree one in input prices, the total cost *TC* and the input prices (*PL* and *PG*) are normalized by the price of capital, *PC*. All variables, except for the time trend, are expressed in natural logarithmic form (*ln*) and are normalized by the sample mean.

We simultaneously estimate the cost function and the inefficiency model, i.e. a linear specification that includes a set of environmental or external factors as explanatory variables of the scaling function multiplied by the truncated normal distribution of the inefficiency term u_{it}. We are going to assume the exogeneity of all the included factors given the short period covered by our data. We test different sets of explanatory variables for the mean inefficiency term: the proportion of the market actually open to competition, switching rates, and the concentration ratio of the market.

Our identifying strategy is based on the impact of market liberalization on firm level efficiency (as measured by a stochastic frontier) exploiting cross-country variation in the extent and timing of policy reforms. In particular we are able to take into account unobserved firm heterogeneity by estimating a fixed effects specification.

We estimate four different specifications, where we alternatively include four different groups of market openness and degree of competition indicators. In all specifications we also include a constant term, year dummies, the population density to control for differences in customers' distribution over the territory of the countries where the companies operate and a nuclear dummy variables to control for the technology of the company.

The inefficiency model is thus:

$$z_{it}'\delta = \delta_0 + \delta_1\, market\_open_{it} + \delta_2\, pop\_density_{it} + \delta_3\, nuclear\_dummy_{it} + \delta_4\, Year\ Dummies + \varepsilon_{it}$$

where, we alternatively include the variables referring to gas and electricity markets openness in $market\_open_{it}$.

4. Data

The dataset consists of an unbalanced panel covering 20 among the largest European energy companies observed over the period 2000-2009[1]. They are big operators employing on average about 37,000 workers. The main sources of the data are the annual reports published by the companies. An effort has been made to make data consistent. In particular many of the considered companies are large corporations, whose lines of business range on several sectors. In the data collection we tried to obtain information about only the energy divisions, in particular the production and distribution of electricity and the distribution and transportation of natural gas. When it was not possible to disentangle the different business lines, we dropped those years where the data for the energy divisions were not available. Moreover our focus is on Europe and we considered only data about the European market.

Total cost *TC* corresponds to total annual operating costs and it is given by the sum of labour (L), material (M) and capital (K) costs. L is given by the total number of employees at the end of the fiscal year, M is mainly given by energy input, while K is the capital stock constructed by the

1 The considered companies are: British Energy, Centrica, DONG AS, E.ON, Electrabel, EDF, Edison, EnBW, Endesa, Enel, Essent, GDF, Gas Natural, Gasunie, Iberdrola, RWE, SSE, ScottishPower, Suez-Tractebel and Vattenfall.

perpetual inventory method. Capital stock at time t is given by $K_t = (1-\delta)K_{t-1}+I_t$, where δ is the capital depreciation rate computed as the ratio of total depreciation expenses to book-valued fixed assets at the beginning of the period, and investments I_t are given by the sum of depreciation expenses and changes in assets between the beginning and the end of the fiscal year.

Labour price *PL* is defined as the ratio of total annual staff costs to the number of employees at the end of the fiscal year. Material price is approximated by the price of natural gas *PG*, expressed in Euro per kWh. It is obtained from Eurostat and it varies over time and across countries. We also experimented with the inclusion of oil price as energy price. Given the high correlation among natural gas and oil prices, we were not able to include both measures and we finally decided for the inclusion of the gas price only as it may better capture energy costs for our set of energy firms.

Following Christensen and Jorgenson (1969), the price of capital *PC* is computed as:

$$PC = \frac{PPC\left(r+\delta\right)}{(1-\tau)}$$

Where, *PPC* is the producer price index for capital goods[2], *r* is an estimated yearly average long term lending interest rate, computed for each company as the ratio between financial expenses and financial debts, while δ is the depreciation rate and τ is the corporate tax rate.

As described above, δ is computed as the ratio of total depreciation expenses to book-valued fixed assets at the beginning of the period. τ is obtained as total paid taxes divided by operating profits, as they appear in the financial statements.

We introduce two output measures in the cost specification: natural gas sale (*y_gas_sale*), and electricity sale (*y_elec_sale).* The two outputs are expressed in annual TWh and information is obtained from companies' annual reports and occasionally from other company publications (as social or environmental responsibility reports). To control for the multi output nature of most included companies, we also insert two dummy variables: *dummy_elec_prod* that takes value equal to one if the firm produces electricity and *dummy_gas_transp* that is equal to one if the company provides gas transportation services. Table 1 shows the number of firms supplying gas, electricity or both. The number of firms supplying both electricity and gas increased over time: 7 firms in 2000 vs 14 firms in 2009. This finding seems to point in favour of the presence of some form of complementarity between gas and electricity distribution, given that the strategy of the main European players is towards diversification.

Descriptive statistics on all variables are presented in table 2. Average total costs amount to about

2 Data source: Eurostat, DS-074567-Industry producer prices index, domestic market - annual data – (2005=100) – MIG - Capital goods.

16,000 Million Euro. The share of labour on total costs is 12% on average, while the share of material and energy is 78% on average. Average gas sales amount to 175 TWh per year, while average electricity sales are 153 TWh. About 87% of our observations come from firms that also produce electricity, while only 19% of sampled company-year couples supply gas transport.

We aim at explaining technical inefficiencies through a set of variables on market and technological characteristics. The variables about the opening of the energy markets are obtained from the European Regulators' Group for Electricity and Gas (ERGEG). The three sets of variables we consider are:

1. *Rate-open-gas* and *Rate-open-elec*: that respectively measure the percentage of the gas / electricity market actually open. A market opening is defined by the percentage that the consumption of the eligible consumers (those allowed to choose electricity/gas supplier) represents as a proportion of total electricity/gas consumption.
2. *Switch-rate-gas* and *Switch-rate-elec*: the actual switching rate of final small customers. They represent the percentage of eligible (small and domestic) consumers who have changed supplier in a particular year.
3. *CR3-gas* and *CR3-elec*: the sum of the market shares of the three main competitors in the gas and electricity retail markets respectively.

All variables vary across countries and over time. The energy market is considered to be open when customers have access to private contract for energy supply on the retail market at end user market prices. The degree of openness of the energy market often depends on the considered customer segment or type: medium to large businesses and energy intensive segments have been the first to be opened. The rate of market openness is based on the volumes sold (total KWh sold), not on the number of customers actually able to freely choose their supplier. We also include population density to control for differences in customers' distribution over the territory and a nuclear dummy for the technology of the company.

Figure 1 shows the trend over the considered sample period in the liberalization and competition indicators over time. By 2007 all countries completed the liberalization process and the declared rate of openness is 100% for both the gas and the electricity industries (figure 1, panel A). Switching rates are in general quite low and they are larger in the electricity sector over almost all observed year (panel B). The market shares of the three main competitors decrease over time, but still are quite high as their average over the period is around 67-68% for both the energy industries. There is some variability over time, but in general CR3 are larger in the gas sector, especially at the beginning of the sample period (panel C).

5. Estimation results

We estimate four different models and results are presented in table 3.

In model (1) we include *Rate-open-gas* and *Rate-open-elec* as explanatory variables for the firms' technical inefficiency. In model (2) we use *Switch-rate-gas* and *Switch-rate-elec*, while in model (3) we include the two measures *CR3-gas and CR3-elec*. Finally, model (4) includes all indicators: market openness (*Rate-open-gas* and *Rate-open-elec*), switching rates (*Switch-rate-gas* and *Switch-rate-elec*) and the degree of concentration CR3 (*CR3-gas and CR3-elec*).

Table 3, panel A shows results from the cost function estimation. Since all variables in the cost function are expressed in logarithm (except for the time trend and the two dummies for electricity production and gas transportation), the coefficients can be interpreted as elasticities. Moreover given the normalization of all regressors by their sample mean, all elasticities are evaluated at sample means.

The electricity coefficient (*y_elec_sale*) is quite stable across specifications and it is always significant. A 1% increase in electricity sales is associated to a 0.26%-0.30% increase in total operating costs. The coefficient for gas sale (*y_gas_sale*) is quite low in magnitude, ranging between 0.03 and 0.07 and it is never significantly different from zero. Squared terms in electricity sales output is always positive and significant, while the interaction term is negative and significantly different from zero in all specifications. Almost all firms in our sample are multi-output firms (see table 1). We account for this by including the output measures for gas and electricity sales and for two dummy variables capturing the effect of electricity production and gas transportation. The inclusion of the additional output measures for the latter two activities was prevented by the high correlation between all the included outputs. In particular the correlation coefficient for our measures for electricity sales and electricity production was higher than 0.85 for all years.

The computation of scope economies is beyond the aim of the present paper, however it could be highlighted the presence of some cost complementarities from the joint activity in the gas and electricity industries, since, at least at the mean point of the sample, the following conditions on the estimated coefficients is always true (see equation (6)):

$\alpha_1\,\alpha_2 + \alpha_3 < 0$

The dummy variable for electricity production (*Dummy_elec_prod*) is always negative and significant in model (2) indicating lower costs for firms producing electricity on their own, with respect to other firms. The parameter estimates for gas transportation (*Dummy_gas_prod*) are not

precisely estimated, probably because only two firms operate also in this segment of the industry.
The input price elasticities are always significant for labour prices, ranging between 0.64 and 0.70. For the average energy firm, labour accounts for 64-74% of total costs, while energy inputs represent 15-30% of total costs. The remaining 5-11% is the share of capital. The actual factor shares for labour and energy are somehow different than the estimated one, with an average labour share that equals 12%, an average energy input share that corresponds to 78% and a remaining 10% for capital (see table 2).

The time trend is significant in only one specification (model 3). The fact that technological change has no effect may be an expected result. In the energy industry, in fact, technological innovation is a slow process, and it is unlikely to find relevant differences over a ten years period.

In the inefficiency model (table 3, panel B) we obtain that the population density is significant only in specifications (2) and (4), with opposite signs. While the dummy for nuclear technology is always positive and significant in specifications (2) and (4). Higher inefficiencies are associated to nuclear powered plants and to companies serving a country with lower population density in the preferred specification (4).

The opening of the market has different effects on inefficiencies depending on the considered market and the included indicator. From model (1) inefficiencies increase when we observe a larger degree of openness in the gas market. On the contrary a higher degree of openness of the electricity market is associated to smaller inefficiencies, but the estimated coefficient is not precisely estimated.

In model (2) the switching rate increases inefficiency in the electricity market, the opposite result is true for the gas market. While in model (3) the degree of concentration is coefficients are not statistically significant.

In model (4) we consider all market liberalization and competitiveness indicators. Results from previous models are confirmed and, moreover, we gain in precision as all coefficients are statistically different from zero.

Liberalization indicators point in opposite directions depending on the considered market: while lower inefficiencies are associated to a larger rate of market openness, a lower switching rate and a lower concentration ratio in the electricity market, exactly the opposite happens for the gas market where lower inefficiencies are linked to a smaller degree of market openness, larger switching rates (even if not significant) and an higher concentration ratio.

Looking at the estimated inefficiency scores, we find them to be quite high in all specifications and show some degree of correlation across the four specifications, except for model (2) (see table 4). Average scores from the preferred specification (model (4)) is 0.92 and the interquartile range amounts to 0.11 (table 5): on average the sampled firms display a degree of inefficiency around 8%, while firms in the third quartile are more efficient than firms in first quartile by 11 percentage points.

Scores are particularly low (and cost inefficiencies are particularly high) in the central period 2003-2005 and since then, they increase. It seems that inefficiencies increased exactly during the years where liberalization was more seriously implemented.

Table 6 breaks down (average) scores according to the activity of firms. Firms supplying only electricity show lower efficiency than gas and diversified firms.

6. Model extensions

As a robustness check we experimented for the inclusion of additional variables in the inefficiency model. First, following Zarnic (2010) we included GDP growth to account for change in demand conditions. While GDP growth is not significant, results did not qualitatively change.

Also we used data from the OECD International Regulation Database (Conway and Nicoletti, 2006). The database consists of a set of indicators on the regulation of energy, transport and communication industries (ETRC). We included a set of indicators for the electricity and the gas markets (the aggregate indicators and some more specific indicators on liberalization, such as the degree of openness of the market to final consumers) in the inefficiency model. Unfortunately OECD data cover up to 2007 and results did not point to any significant effect, also probably because of the shorter data coverage.

Given the quite small estimated coefficients for output measures, we also estimated a translog cost function using Seemingly Unrelated Regressions (SUR) which allows for the simultaneous estimation of the cost function and input share equations obtained applying the Shephard's lemma to equation *(6)*. While the estimated input shares more closely mimic the actual ones, results on output elasticities are confirmed.

Finally we tried to interact competitiveness and liberalization measures, by extending the model specification (4). The interaction terms did not show to have explanatory power in the inefficiency model.

7. Concluding remarks

The aim of the work is to examine the potential impact of liberalization on the cost of the main energy firms in Europe. The literature on the link between competition and market liberalization is large and still growing in Europe. Liberalization, such as the removal of entry barriers, or the abolition of state monopolies, is usually associated to larger competition among firms. On the contrary theoretical and empirical findings on the effects of a more competitive environment on firms' performance are less clear cut. To the best of our knowledge there are no studies that consider the effect of liberalization, where all customers will be able to choose their energy (electricity and/or gas) supplier, on firms' efficiency. We estimate a stochastic cost frontier for a sample of 20 firms among the largest European energy companies observed over the period 2000-2009. Our identifying strategy is based on the impact of market liberalization on firm level efficiency (as measured by a stochastic frontier) exploiting cross-country variation in the extent and timing of policy reforms. In particular we are able to take into account unobserved firm heterogeneity by estimating a fixed effects specification (Greene, 2005a, b; Wang and Ho, 2010).

The opening of the market has different effects on inefficiencies depending on the considered indicator. In general inefficiencies decrease when the market is open and more competitive, especially in the electricity sector. A higher market concentration ratio is associated to lower inefficiencies, especially in the gas industry.

From the policy perspective, these findings seem to suggest that introducing competition in the supply market by giving the consumers the opportunity of choosing their supplier is a good choice also in terms of firms’ performances. Nevertheless, the effects on firm performance are different depending on the considered indicators. More efficiency is associated to a more open and competitive environment for the electricity sector, while the same firms do enjoy lower efficiency when the gas market is open and competitive. Probably gas and electricity markets are too different environments and competition indicators act in opposite directions in the two industries.

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Table 1. Sample description: Count of firms supplying gas, electricity or both products

Year	Gas	Electricity	Gas and Electricity	Total Number of Firms
2000	4	6	7	17
2001	3	7	7	17
2002	3	7	9	19
2003	2	4	14	20
2004	2	4	13	19
2005	1	4	13	18
2006	1	4	13	18
2007	0	1	14	15
2008	0	0	15	15
2009	0	0	14	14
Total Number of Observations	16	37	119	172

Notes: Firms supplying gas are retail gas suppliers. Electricity firms are both electricity retailers and generators.

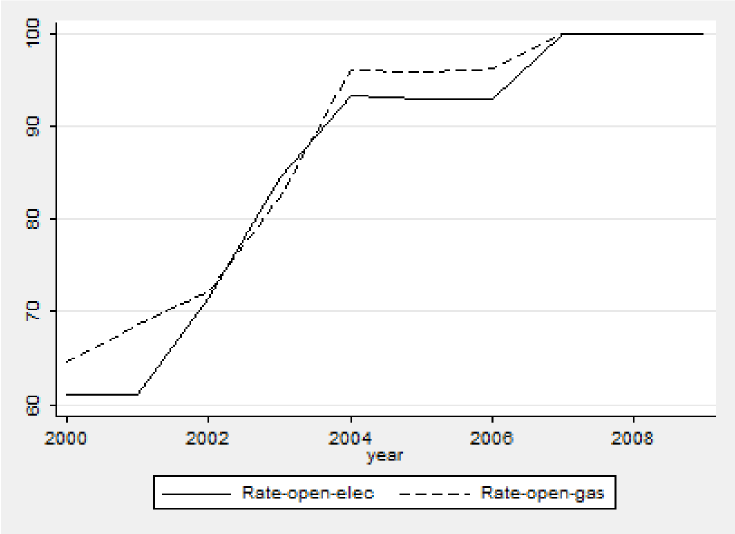
Table 2. Descriptive statistics for the main included variables.

Description	Variable name	Mean	SD	Median	Min	Max
Total operating costs (Mil. Euro)	*TC*	16,200	14,800	10,700	463	70,648
Input measures						
Labour price (th. Euro per worker)	*PL*	58.72	14.54	58.28	34.27	115.98
Gas price (Euro/kWh)	*PG*	0.02	0.01	0.02	0.01	0.04
Labour share	*SL*	0.12	0.06	0.11	0.01	0.28
Material share	*SM*	0.78	0.09	0.78	0.56	0.98
Output measures						
Gas sale (TWh)	*y_gas_sale*	175.08	239.69	74.60	0.00	1211.00
Electricity sale (TWh)	*y_elec_sale*	152.53	161.14	98.41	0.00	731.40
Dummy for electricity production	*Dummy_elec_prod*	0.87	0.33	1.00	0.00	1.00
Dummy for gas transportation	*Dummy_gas_transp*	0.19	0.39	0.00	0.00	1.00
Inefficiency model						
% openness electricity market	*Rate-open-elec*	85.13	23.73	100.00	30.00	100.00
% openness gas market	*Rate-open-gas*	87.00	22.73	100.00	20.00	100.00
% Switch rate in the electricity market	*Switch-rate-elec*	6.84	6.76	4.00	0.00	22.00
% Switch rate in the gas market	*Switch-rate-gas*	6.08	7.29	3.47	0.00	35.00
Concentration ratio in the electricity market	*CR3-elec*	66.83	18.89	62.00	15.00	100.00
Concentration ratio in the gas market	*CR3-gas*	68.65	25.05	75.00	10.00	100.00
Dummy for nuclear plants	*nuclear_dummy*	0.40	0.49	0.00	0.00	1.00
Population density (people/Km^2)	*pop_density*	198.88	117.89	204.00	21.60	487.20

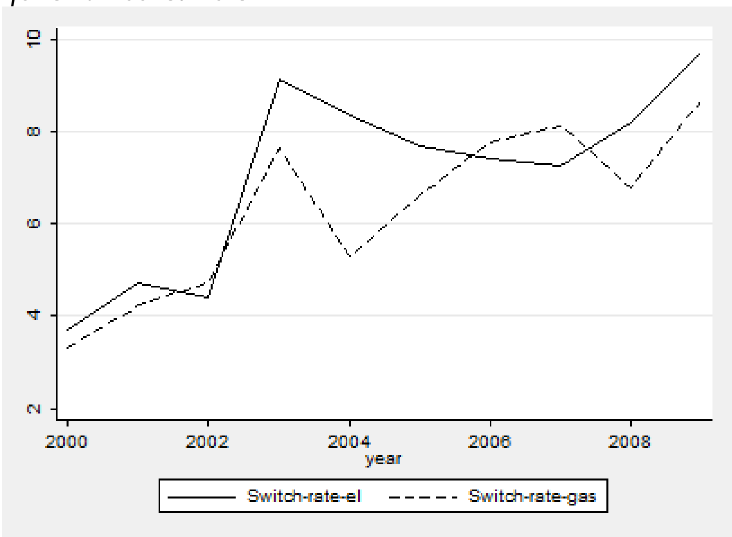
Notes: All monetary values are deflated using the Harmonized Consumer Price Index by Eurostat (base year is 2005). Unbalanced panel of 20 firms observed over the period 2000-2009. Total number of observations 172.

Figure 1. Trend in the liberalization and competitiveness indicators (yearly average)

Panel A. Rate of openness of the retail market



Panel B. Switching rate for small consumers



Panel C. Concentration ratios in the retail market

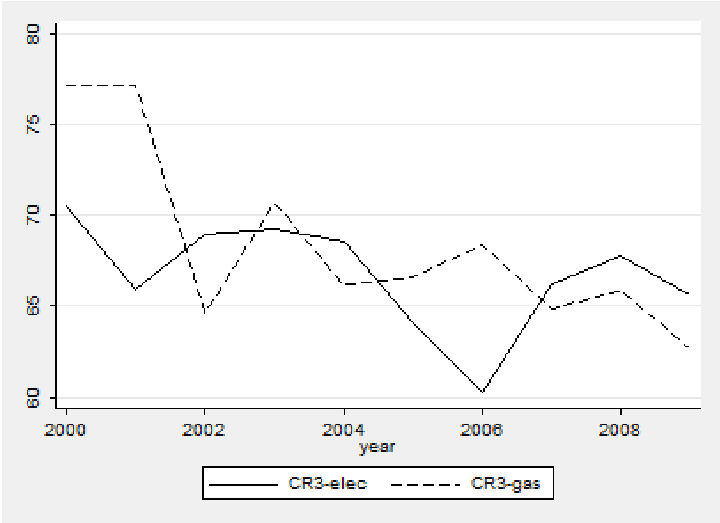


Table 3. Stochastic Frontier Cost estimation results.
Panel A. Cost model

	(1)	(2)	(3)	(4)
Ln(y_gas_sale)	0.053	0.034	0.066	0.025
	(0.05)	*(0.03)*	*(0.05)*	*(0.04)*
Ln(y_elec_sale)	0.274***	0.301***	0.279***	0.256***
	(0.07)	*(0.05)*	*(0.08)*	*(0.06)*
Ln(y_gas_sale)^2	-0.009	0.011*	-0.010	0.004
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*
Ln(y_elec_sale)^2	0.024*	0.028***	0.025*	0.023**
	(0.01)	*(0.01)*	*(0.02)*	*(0.01)*
ln(y_gas_sale)ln(y_elec_sale)	-0.034***	-0.018**	-0.027***	-0.046***
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*
Ln(PL)	0.741***	0.697***	0.726***	0.636***
	(0.13)	*(0.10)*	*(0.14)*	*(0.12)*
Ln(PG)	0.154	0.281**	0.163	0.308**
	(0.15)	*(0.11)*	*(0.16)*	*(0.12)*
Ln(PL)^2	-0.012	0.149	-0.085	0.444
	(0.38)	*(0.28)*	*(0.37)*	*(0.31)*
Ln(PG)^2	1.427***	1.151***	1.307***	1.403***
	(0.40)	*(0.29)*	*(0.39)*	*(0.31)*
Ln(PL)ln(PG)	-0.861**	-0.750***	-0.768**	-1.017***
	(0.35)	*(0.26)*	*(0.34)*	*(0.28)*
Ln(PL) Ln(y_gas_sale)	0.061**	-0.004	0.032	0.008
	(0.03)	*(0.02)*	*(0.02)*	*(0.02)*
Ln(PL) Ln(y_elec_sale)	0.076	0.058	0.073	0.097**
	(0.05)	*(0.04)*	*(0.06)*	*(0.04)*
Ln(PG) Ln(y_gas_sale)	-0.041*	0.009	-0.016	-0.014
	(0.03)	*(0.02)*	*(0.02)*	*(0.02)*
Ln(PG) Ln(y_elec_sale)	-0.084*	-0.053	-0.076	-0.088**
	(0.04)	*(0.03)*	*(0.05)*	*(0.04)*
Dummy_elec_prod	-0.334	-0.508**	-0.333	-0.257
	(0.27)	*(0.20)*	*(0.30)*	*(0.22)*
Dummy_gas_transp	-0.157	0.227	-0.089	-0.177
	(0.27)	*(0.19)*	*(0.30)*	*(0.21)*
Trend	0.045	0.006	0.063*	-0.046
	(0.03)	*(0.02)*	*(0.03)*	*(0.03)*
Trend^2	-0.000	0.001	-0.002	0.006**
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*

Panel B. Inefficiency model

	(1)	(2)	(3)	(4)
nuclear_dummy	0.376	1.529*	0.129	1.092**
	(0.89)	*(0.88)*	*(1.08)*	*(0.54)*
pop_density	-0.134	0.038***	-0.633	-0.040**
	(0.10)	*(0.01)*	*(7.97)*	*(0.02)*
Rate-open-gas	0.007***			0.102**
	(0.00)			*(0.05)*
Rate-open-elec	-0.005			-0.058***
	(0.01)			*(0.02)*
Switch-rate-gas		-0.391***		-0.024
		(0.11)		*(0.05)*
Switch-rate-elec		3.530***		0.543**
		(0.10)		*(0.25)*
CR3-gas			-0.906	-0.111**
			(9.28)	*(0.04)*
CR3-elec			1.275	0.198**
			(14.92)	*(0.10)*
Time Dummies	Yes	Yes	Yes	Yes
σ^2_v	-3.114***	-3.708***	-2.980***	-3.614***
	(0.12)	*(0.12)*	*(0.12)*	*(0.12)*
σ^2_u	19.638	-136.282	-0.368	-28.430*
	(15.51)	*(.)*	*(978.68)*	*(17.11)*
logL	18.21	60.71	9.86	42.40
N.obs	172	172	172	172

*Notes: Dependent variable: natural logarithm of total operating costs, normalized by the capital price. Robust SEs in parenthesis. All estimates performed by the command 'sf_fixeff' for Stata 10.1, by Wang and Ho (2010). In the estimation of the standard translog specification, zero output levels are substituted by the value 0.01. ***, ** and * indicate significance at 1, 5 and 10% level, respectively.*

Table 4. Spearman rank correlation coefficients for the estimated inefficiency scores (the star indicates that the correlation is significant at 1% level)

Model	(1)	(2)	(3)	(4)
(1)	1.000			
(2)	-0.130	1.000		
(3)	0.673*	-0.060*	1.000	
(4)	0.538*	0.482*	0.386*	1.000

Table 5. Distribution of estimated inefficiency scores from model (4).

Year	Mean	SD	1st Quartile	Median	3rd quartile	N. firms
2000	0.931	0.161	0.991	1	1	17
2001	0.915	0.157	0.921	0.996	1	17
2002	0.911	0.148	0.874	0.979	1	19
2003	0.841	0.216	0.761	0.922	0.998	20
2004	0.882	0.205	0.804	0.995	1	19
2005	0.883	0.2	0.805	0.979	1	18
2006	0.900	0.179	0.841	0.984	1	18
2007	0.992	0.0137	0.988	1	1	15
2008	0.971	0.0536	0.969	0.999	1	15
2009	0.968	0.056	0.968	0.993	1	14
Total	0.915	0.162	0.887	0.996	1	172

Table 6. Mean estimated inefficiency scores by activity sector. Estimates based on model (4).

Year	Gas	Electricity	Gas and Electricity	Total
2000	0.971	0.835	0.990	0.931
2001	1.000	0.820	0.974	0.915
2002	0.999	0.868	0.914	0.911
2003	0.998	0.594	0.889	0.841
2004	0.982	0.713	0.919	0.882
2005	0.938	0.707	0.934	0.883
2006	0.883	0.728	0.954	0.9
2007		0.988	0.992	0.992
2008			0.971	0.971
2009			0.968	0.968
Total	0.979	0.778	0.949	0.915