Faculdade de Economia
da Universidade de Coimbra

Grupo de Estudos Monetários e Financeiros
(GEMF)
Av. Dias da Silva, 165 – 3004-512 COIMBRA,
PORTUGAL

gemf@fe.uc.pt
http://gemf.fe.uc.pt

VÍTOR MARQUES, ISABEL SOARES, & ADELINO FORTUNATO

UNIFORM PRICE MARKET AND BEHAVIOUR PATTERN: WHAT DOES THE IBERIAN ELECTRICITY MARKET POINT OUT?

ESTUDOS DO GEMF

N.º 8 2008

PUBLICAÇÃO CO-FINANCIADA PELA FUNDAÇÃO PARA A CIÊNCIA E TECNOLOGIA

Impresso na Secção de Textos da FEUC
COIMBRA 2008

"UNIFORM PRICE MARKET AND BEHAVIOUR PATTERN: WHAT DOES THE IBERIAN ELECTRICITY MARKET POINT OUT?"

Vítor Marques, ERSE[1]; Isabel Soares, University of Porto; Adelino Fortunato, University of Coimbra

Vítor Marques, vmarques@erse.pt, Rua Shegundo Galarza n.º5 4º A 1750-436 Lisboa Portugal, (351) 213033224

Abstract

The electricity spot markets can be considered as capacity constrained markets (Kreps and Scheinkman, 1983), where market price definition depends on the quantity strategies. In this theoretical framework, the main target of the present paper is to show to what extent a spot market organized like a Uniform Price Auction (UPA) is naturally inclined to develop anti-competitive practices, in particular through quantity strategies. To achieve this objective, multivariable models are defined for each daily demand period of the Iberian electricity market. Each model correlates the hourly market price change and the bid quantities of the two main Iberian producers (Endesa and Iberdrola), for every summer between 2001 and 2004. To apply those models one has to solve the endogeneity problem. This exercise is also useful to highlight any anti-competitive behaviour. Quantities produced by the producers with infra marginal bids should not be endogenous when there is no risk that they will not be dispatched, unless producers have some expectations about the system marginal price. In addition, this kind of endogeneity reinforces the model's theoretical assumption that change in the system marginal price stems from quantity strategies. The models present some expectable but interesting results. Those results show that even base load units' bids may depend on expectations about the system marginal price evolution. Those expectations can reflect market strategies. Therefore, in a market where the main companies own base load and peak load units, like the Iberian wholesale electricity market, the UPA is an open window to anti-competitive practices based on quantity strategies, such as the raising of the system marginal price through the capacity withdrawal from base load units.

Keywords: oligopoly, electricity, endogeneity, uniform-price market

JEL classification: L13

[1] The results and comments presented in this paper are entirely the authors' responsibility and do not reflect the official opinions of ERSE or other institution.

Introduction

Market design can have a significant influence on anticompetitive practices. The Iberian market, like the former Spanish market, is organized like a UPA. It is the generator which sells the marginal quantity that defines the system marginal prices. Those prices pay all the accepted bids. The main alternative to the UPA is the Pay-As-Bid auctions (PABA) also called discriminatory auctions. In those markets, the energy sold by the producers is paid at the price of their bids. With the exception of the England and Wales balancing market (British Electricity Trading and Transmission Arrangements - BETTA[2]), most of the electricity wholesales markets are organized as UPA.

In a competitive PABA market all producers would receive their long term marginal costs. In the UPA, the bids may reflect short term marginal costs and, at half peak hours and off-peak hours, the base load units' prices bid can even be lower than their marginal costs, as those units only need to warrant their dispatch. In fact, they already know that the system marginal price will cover their short term and long term marginal costs. The UPA is based on the spot pricing theory (Caramanis, 1982), which claimed that the spot electricity market can provide efficient outcome both in the short and in the long run, because the system marginal price defined by a marginal technology with an almost zero fixed cost will cover the fixed and variable costs of the remaining power plants. Any spike in the system marginal price would attract new investments. Those spikes are called scarcity rent. But this situation is theoretical (see for example Joskow, 2006). In practice, it has been difficult for regulatory agencies to distinguish between scarcity rent and market power (Roques et al, 2005).

Until recently UPA was more popular with academics than PABA. Thus, A. Kahn, P. Cramton, R. Porter, R. Tabors (Kahn et al. 2001) argued that PABA is not efficient because it raises costs and leads to anticompetitive practices. PABA may raise prices because producers have to bid prices higher than their short term marginal costs to cover their common or fixed costs. Therefore, their bids would be close to what they expected to be the system marginal price. If producers are risk averse, this inefficient

[2] Former NETA, New Electricity Trading Arrangement

effect will worsen. The consequence of those expectations for their bids is that they fail to reflect the marginal costs and the total cost-minimizing merit order dispatch can, inevitably, no longer be assured. So the supply curve is "flattening". On the other hand, forecasting the system marginal price is costly and would be added to the production costs. PABA would also lead to anticompetitive practices because less efficient generators can produce more, and the more efficient producers can increase their mark-up. In the UPA markets, on the other hand, the producers' incomes would reflect their efficiency. The last main criticism of PABA, is that it needs both knowledge and scale economies to forecast the system marginal prices. Therefore, PABA would discourage new investment and, most of all, it would raise barriers to the entry of new small producers.

The above arguments led some authors to predict a less than promising future for the British NETA (Wolfram, 1999; Hogan, 2001). But one year after the implementation of NETA, in March 2001, with PABA rules, energy prices decreased 20%.

Since then, many studies have pointed out contradictory conclusions in relation to the comparison between PABA and UPA.

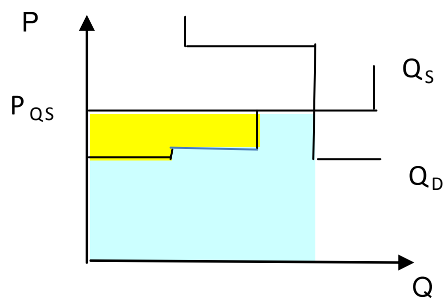
Some studies show that the collusion risk is higher in the UPA than in the PABA (Fabra, 2003 and Kemplerer, 2002) and, under certain conditions[3], the average price (and the mark-up) is lower in the PABA than in the UPA (Holmberg, 2005). On the other hand, other analyses have concluded that the mark-up would be lower and the consumer surplus would be higher in the PABA (Federico and Tahman, 2003)[4]. But this same study also pointed out that whenever producers already have market power they may react non-efficiently in the PABA, leading to lower output and poorer welfare. Moreover, an empirical work (Rassenti et al., 2003) showed that, under certain demand conditions, the mark-up in PABA with no structural market power converges to the prices of a UPA with structural market power; nevertheless, price volatility is lower in the PABA than in the UPA. Another empirical

[3] As soon there is pure strategy equilibrium, which is not always found in the PABA, but always exists in the UPA.
[4] This is corroborated by A. Phillpott (2007) who pointed out that in certain conditions welfare and consumer surplus is lower in the UPA than in the PABA.

work should be mentioned (Yamamoto and Tezuka, 2005) which showed that the PABA, by promoting competition, is more positive for small producers than the UPA, since the bids' curves are flatter in the first case.

Figure 2 compares UPA producers' income (yellow and blue areas) and PABA producers' income (blue area), in a situation where the system market price is the same and there is no "flattening" curve effect of the PABA.

Figure 1- PABA and UPA producers income



Therefore, there is no consensus about the most efficient market design. It depends on the study's conditioning and assumptions. However, in Europe most of the wholesale energy markets, which are highly concentrated, are organized as UPA.

The Iberian wholesale market is also a highly concentrated market. Hence, anti-competitive strategies, such as tacit collusions, can easily appear. In a UPA, anti-competitive strategies can be developed without raising the mark-up. As every producer receives the system marginal price, large ones only have to withhold some capacity when demand is less elastic to lever up the system marginal price. This way, they will significantly increase their income above the competitive level. However, it is almost impossible for an outside entity to determine if a generating unit declared forced out was actually able to run (Wolak, 2001). It has to be highlighted that power is easier to monitor in the PABA the market, to the extent that production costs are known, since the mark-up analysis can be applied to each producer's accepted bids.

Therefore, in a UPA case, like the Iberian wholesale market, it can be useful to implement an approach which highlights any possible anticompetitive practice, which would be based not on the mark-up analysis, but on the characteristics of UPA markets instead. So, considering the importance of quantity strategies in the UPA markets, the present work developed a model which correlates the system marginal price and the quantities supplied in order to present some possibles consequences of quantity strategies in the hourly price setting.

Thus, our approach also intends to shed some light on the debate over the choice between UPA and PABA design.

I The model

First of all, the relation between the system marginal prices and the quantities supplied has to be explained. For this, the equations below synthesize the operation of the Iberian electricity wholesale spot market, on the supply side, assuming that the demand is an external variable[5].

$$\begin{cases} P_{fe} = F(Q) \\ Q_s - Q_d = 0 \end{cases} \qquad (1)$$

$$\frac{dP_s}{dQ_s} \geq 0 \qquad (2)$$

$$Q_s = \sum_{i=1}^{i=F_e} Q_i \qquad (3)$$

$$P(Q_i) \geq P(Q_{i-1}) \qquad (4)$$

The market clearing price (or system marginal price), P_{fe}, is a function of the volume, which results from the crossing of demand matched quantity curve, Q_d and supplied matched quantity curve, Q_s (equation 1).

[5] Nevertheless, we are conscious that those companies are vertically integrated and they can, in theory, coordinate their supply and demand side strategies. However, we assume that in a uniform price market this strategy would be difficult to achieve.

The supply curve prices, P_s, rise with the amounts bid (equation 2). The supply curve results from the sum of each producer (units, or external agent) power bid, matched, Q_i, ordered in a growing way with the price offered by each agent (equations 3 and 4).

Introducing a time factor, to make the model dynamic, the supplied amount function Q_{ti}, matched in the daily UPA market at hour *t*, for the producer *i*, is determined as follows:

$$Q_{ti} = F(P_{ti}, S_{ti}, K_{ti}, \theta_{ti}, \varepsilon_{ti})\ ^{6} \qquad (5)$$

Where P_{ti} is the producer *i's* bid price at hour *t*, S_{ti} is the residual demand facing producer *i* by the hour *t*, considering the amounts supplied by its competitors, K_{ti} is the capacity imposed by the hour *t*, θ_{ti} is the producer's strategy and ε_{ti} is a random variable .

One of the factors that bid prices depend on is production costs. The producers with higher production costs should present higher bid prices.

The residual demand can be expressed as follows:

$$\begin{cases} S_{ti} = \sum_{j \neq i} Q_{tj} \\ S_{ti} = Q_{ts} - Q_{ti} \end{cases} \qquad (6)$$

Where Q_{tj} is the quantity supplied and matched in hour *t* by the producer $j \neq i$ and Q_{ts} is the overall quantity supplied per hour *t* by the market.

Since the amount supplied by the producer, *fe*, with the highest bid price matched, Q_{tfe} defines the market clearing price and Q_{ts} includes Q_{tfe} ; inequality (4) can be rewritten as follows:

$$(7)\ P_{(Q_{ts})} = P_{(Q_{tfe})} \geq P_{(Q_{ti \neq fe})}$$

Where $P_{(Qts)}$ is the market clearing price proceeding from the crossing of the demand matched quantity curve, Q_d, and supplied matched quantity curve, Q_s; $P_{(Qt\,fe)}$ is the price offered by producer *fe*; and $P_{(Qt\ i \neq fe)}$ are the prices bid per hour *t* by infra-marginal producers, $i \neq fe$, whose bid quantities were matched, $Q_{t\ i \neq fe}$.

[6] This specification underlies the relation between price and quantities matched.

The second-price sealed bid auction occurs for producers, *i≠fe,* who do not define the market clearing price. Thus, those producers optimally bid their output at the marginal cost, since they receive the system marginal price and then can recover all their costs (fixed and variable) bidding their short term marginal costs. Equations (7) and (5) can be rewritten as follows:

$$P_{(Q_{ts})} = P_{(Q_{tfe})} \geq P_{(Q_{ti \neq fe})} = Cmg_{(Q_{ti \neq fe})} \qquad (8)$$

$$Q_{t\,i \neq fe} = F(Cmg_{t\,i \neq fe}, S_{ti \neq fe}, K_{t\,i \neq fe}, \theta_{t\,i \neq fe}, \varepsilon_{t\,i \neq fe}) \qquad (9)$$

Where $Cmg_{t\ i \neq fe}$ are the marginal costs implicit in the prices bid by the remaining producers, *i≠fe*, at each hour *t*.

Under a perfect competition assumption, equation (9) is widened to all producers:

$$Q_{ti} = F(Cmg_{t\,i}, S_{ti}, K_{t\,i}, \varepsilon_{t\,i}) \qquad (10)$$

Equation (10) is one of the arguments of UPA supporters, who say that it is easier to regulate the market power in a UPA than in a PABA, since in the first case the regulator only has to analyse the mark-up implicit in the bid which defines the price and doesn't have to analyse all bids.

Therefore, in a competitive market a producer with higher production costs should submit higher bid prices and the quantities supplied by this producer should be the quantities that define the market clearing price. Thus, the industry's optimal bid function will correspond to the industry marginal cost function.

Then, in an electricity wholesale spot market, without anti-competitive practices, one would expect that:

- The system marginal price rises with the demand.
- The energy produced by the producers with the highest production costs is linked to the highest bid prices, which defines the system marginal price.

But on the other hand, relation (7) is an increasing and convex function, which can be expressed as follows:

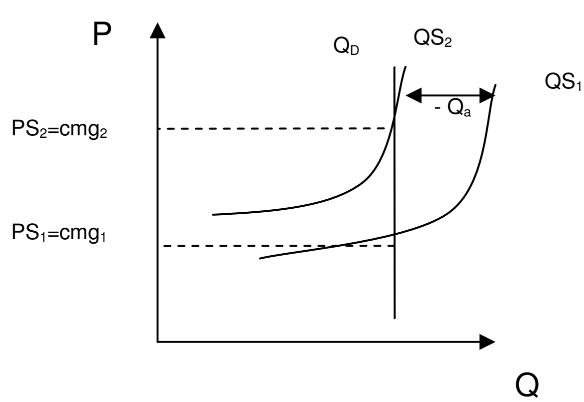
$$\begin{cases} \dfrac{dP_{t\,fe}}{dQ_{(Cmg_{ts})}} \geq 0 \\ \dfrac{d^2P_{t\,fe}}{dQ^2_{(Cmg_{ts})}} \geq 0 \end{cases} \qquad (11)$$

Where $Q_{(Cmg_{ts})}$ is the spot market quantity function, which depends on cmg_{ts}, the spot market marginal cost function. $Q_{(Cmg_{ts})}$ is an increasing and concave function in cmg_{ts}, since the highest marginal costs' producers produce less, and in fewer hours, than those with lower marginal costs, which produce more each hour and for the whole day. Thus the marginal cost function, and therefore the system marginal price function, rises faster than the quantity supplied function:

$$\begin{cases} \dfrac{dQ_{ts}}{dCmg_{ts}} \geq 0 \\ \dfrac{d^2Q_{ts}}{dCmg_{ts}^{\;2}} \leq 0 \end{cases} \qquad (12)$$

Therefore, the market price can be significantly levered up through capacity withholding, maintaining the equality of prices and marginal costs, as can be seen in the following figure, where demand is inelastic:

Figure 2- Withholding capacity effect in a UPA



This kind of strategy is analogous to Cournot behaviour (except that the marginal producer defines the price, rather than the auctioneer), taking into account that producers dump the quantities they produce. Nevertheless, producers' bid strategies are quantity and price mixed (see Green and Newberry, (1992), and von der Fehr and Harbord (1993)), bid quantities influence the system marginal price more in a UPA market than bid prices do, as Wolak and Patrick (1996) pointed out for the former England and Wales electricity spot market,.

Competition in electricity spot markets with a UPA design can therefore be analyzed as a Bertrand game with capacity constraints, as Armstrong, M., Cowan, S. and Vickers, J. interpreted the former England and Wales electricity spot market (Armstrong, et al ,1994) and Kreps and Scheinkman previous work can be recalled (Kreps and Scheinkman, 1983). Those authors have shown that in a capacity constrained industry, if the residual demand is defined through the efficient rationing rule, there is a two-stage game, where at the first stage the producers define the capacity and at the second stage they define the prices. The outcome is similar to the one-stage Cournot outcome.

Others authors (see Tirole, 1988) have shown that firms have an incentive to raise prices above the Cournot market clearing price when the efficient rationing rule assumption is released and the rationing rule is, for example, the proportional one, closer to what occurs in the energy wholesale markets. In a capacity constraint market, therefore, such is the electricity wholesale market that the Cournot outcome should be the bottom limit for the market clearing price, even with a price game.

Taking the Cournot model's first order condition for profit maximization of producer *i,* that producer will produce extra units until:

$$\pi_{(Qti)} = P_{(Qts)} - Cmg_{(Qti)} + Q_{(Cmg_{ti})} Pmg_{(Qts)} = 0 \qquad (13);$$

where $\pi_{(Qti)}$ is the profit function of producer *i* concave in Q_{ti}, $Cmg_{(Qti)}$ is the marginal cost function of producer *i,* $Q_{(Cmg_{ti})}$ is the supply cost function of producer *i* and $Pmg_{(Qts)}$ is the marginal cost function of the spot market.

The third term of the function reckons the impact of the extra unit on the profitability of the units already produced, since the extra unit leads to a decrease of $Pmg_{(Qts)}$. The third term is linked to the quantity strategies, which would not exist in a competitive electricity wholesale market, because producers would be too small to influence the market prices. In a market with few players like the Iberian wholesale market, this third term would be different from 0.

So how can the significance of quantity strategies in the hourly marginal price definition system be established? The answer can be found if the previous equations are reanalysed.

Taking into account relations (1), (2) and (11), one can test a model which compares the influence for each producer of the hourly quantities supplied by technologies and the total demand on the hourly marginal price system evolution. Considering the UPA characteristics, it is assumed that the hourly quantities supplied by technologies depend on the producers' strategies, as well as other factors such as marginal costs and capacity constraints. As marginal costs and, consequently, the system marginal prices, vary significantly during the day, due to the daily fluctuation of demand and the technical characteristics of supply[7], which are independent of the producers' strategies, the analysis has to be done for different periods of the day. Three periods of the day are usually identified, taking into account the demand level and the system marginal price, and they are: peak hours, half-peak hours and off-peak hours.

If the analysis is extended to more than one year to enlarge the sample, other variables have to be added. These are linked to the production cost evolution and to structural changes, which vary on a monthly or annual basis, and can raise or lower the system marginal price. However, this is a descriptive approach, but not a structural one. Therefore, we choose to give some clues about the behaviour in the wholesale market in opposition to a deterministic approach.

Therefore, this descriptive approach has two time levels, the short term level and the medium or long term level.

The first "step" of the analysis is the definition, for each period of the day, of a multivariable model which related the hourly system marginal prices evolution and quantities supplied.

[7] The capacity constraints, the fact that power is not storable, the huge marginal costs' difference between technologies, etc

The multivariable model can be defined as follows:

$$P_{tfe} = \beta_s Q_{ts} + \beta_i Q(\theta_i)_{ti} + \beta_k C_k + \beta_m \varepsilon_m \qquad (14)$$

Where, for each hour t, P_{tfe} is the system marginal price, Q_{ts} is the global demand, $Q(\theta)_{ti}$ are the quantities supplied by producer *i* taking into account strategy θ_i[8], C_k is the cost factor k, and ε_m are the remaining factors, i.e. factors due to structural changes.

However, this model demands the solving of the endogeneity problem. Therefore, the second "step" is the endogeneity analysis.

We can affirm that there is some endogeneity between the market clearing price, P_{tfe}, and the overall amount supplied in the market, $Q_{s(Ptfe)}$,, as well as between the market clearing price and the quantity supplied by the producer with the highest bid price, $Q_{(Ptfe)}$. The simultaneity between the dependent and the independent variables is only one of the reasons for the occurrence of endogeneity. The other reasons are:

- An important factor that is correlated to the independent variable is omitted.
- There is a measurement error in an explanatory variable.
- It is a dynamic model involving expectations.

Assuming that there is no measurement error, $Q_{(cmgti \neq fe)}$, the quantities produced by the producers with infra marginal bids (base load and intermediate units), which are sure to be dispatched, are not endogenous unless there are expectations about the system marginal price whenever the producers submit their bids or an important factor that is correlated to the independent variable is omitted. As base load units are despatched independently of the prices they bid and, hence, of their marginal costs, the endogeneity will be due to the link between infra marginal producers' bid quantities and their system marginal price expectations. When a base load unit belongs to a company owing a major set of power plants with different technologies and, therefore, with different marginal costs, those expectations can be incorporated into strategies to lever up system marginal prices, thereby increasing the income of the

[8] Which can be anything between the pure strategic behaviour and the marginal costs and the capacity constrained.

company. At this point, it has to be remembered that the quantity supplied in an electricity spot market is an increasing and concave function in marginal costs, since the producers with high marginal costs produce less at hour *t*, than those with low marginal costs, i.e, the marginal cost function, and therefore the system marginal price function, rises faster than the quantity supplied function. To increase a "multi-unit" company income in a UPA market, one only has to withdraw some capacity of a base load unit belonging to this company. Therefore, the suspicion of anti-competitive behavior raised by the endogeneity analysis is confirmed when any inverse correlation between the system marginal price and the quantity supplied by a base load unit is highlighted by the model. As the anticompetitive strategies in UPA markets, related to capacity withholding, are difficult to prove, the endogeneity analysis helps to resolve this issue.

If the quantities produced by the producers with infra marginal bids are endogenous and are inversely correlated with the system marginal price evolution, this would be strong evidence that producers develop quantity strategies in order to increase the system marginal price.

The instrumental variables used to remove the endogeneity between the system marginal price and quantities supplied can confirm this assumption.

For the external variable, the endogeneity can be explained by the omission of explanatory variables. In the dummy variables case, as it can include independent and external factors, the endogeneity can be due to the set of reasons already referred.

The third step of the analysis is the validation of the explanatory model through the definition of the final models, after endogeneity has been removed. The relation between the system marginal price and the quantities produced has to be different for each technology according to the period of the day. Thus, at base load hours, quantities produced by base load technology units should define the system marginal prices and at peak hours it has to be peak load technology units which define the price. The influence of the demand should be higher for base load hours, when demand is more elastic, and should be lower for peak hours when demand is less elastic.

In the following section, the framework of the empirical analysis and the resulting definition of the model's variables are presented.

II The empirical analysis

1 The Spanish wholesale market until 2004

The present work analyses the period between 2001 and 2004. Three years earlier, in 1998, the Spanish wholesale market was created and it lasted until July 2007, when it was merged with the Portuguese wholesale market to form MIBEL, which embraces both the forward market, (OMIP), and the spot market, (OMIE). Until July 2007, OMEL was the operator of the market.

This market was divided into a daily market and an intra-daily market, like the current OMIE. In the daily market, the producers submit for the next day, on an hourly basis, bids[9] of amounts of electricity at a minimum price and the buyers (distributors, traders and eligible consumers) submit hourly bids of power demand at a maximum price. Based on those bids, OMEL builds the hourly purchase and sale electricity curves. Each hourly market price results from the crossing of these curves, that is, of the matching between the purchase and sale bids. However, the bid would only be accepted if the price submitted by the generator is equal to or lower than the system marginal price. Like the present definition of OMIE, this market was a uniform-priced auction (UPA) since the energy sold there by generators should be paid at the system marginal price. In the intra-daily market, the final adjustments are made on the current day, in order to adjust the supply and the demand. The daily market has been the main market: during the analysed period, more than 90% of the electricity was traded in the daily market. The final price of the power sold came mainly from the daily market, which represented from 70% to 80% of this price, with the remaining amounts proceeding from the capacity payment of the intradaily market and from the operation of the system.

[9] Each hourly bid is composed of 10 different quantity/price pairs.

After the creation of the wholesale market, Spanish generators lost the warranty they had on the payment of their investments, which was allowed by the former legal framework. In order to recover those stranded costs, a transition regime was established, Costes de Transición a la Competencia, CTCs, that allowed the companies which owned power stations to receive compensation for the loss of revenues. Endesa benefited more from CTCs than any other company. This dependency had grown since 1998, because Endesa had invested less in new generation capacity than its competitors, that is to say, less than Iberdrola.

This transition regime lasted until 2006, when the CTCs were abolished. With the complete liberalization of the Portuguese electricity system in 2007, a transition regime similar to CTCs was established, the CMECs.

As

Figure 3 shows, the installed capacity of the Spanish power market rose after liberalization, mainly due to investments in:

- Renewable power plants (special regime), which were not traded in the Spanish wholesale market.
- Natural gas combined cycle power plants (NGCC), since 2002.

Endesa invested in NGCC before Iberdrola did, at the beginning of 2002. However, after 2004 Iberdrola had more NGCC installed capacity than Endesa. The weight of CTCs in some companies' portfolios decreased significantly after 2004.

Figure 3- Installed capacity generation in Spain between 1997-2004

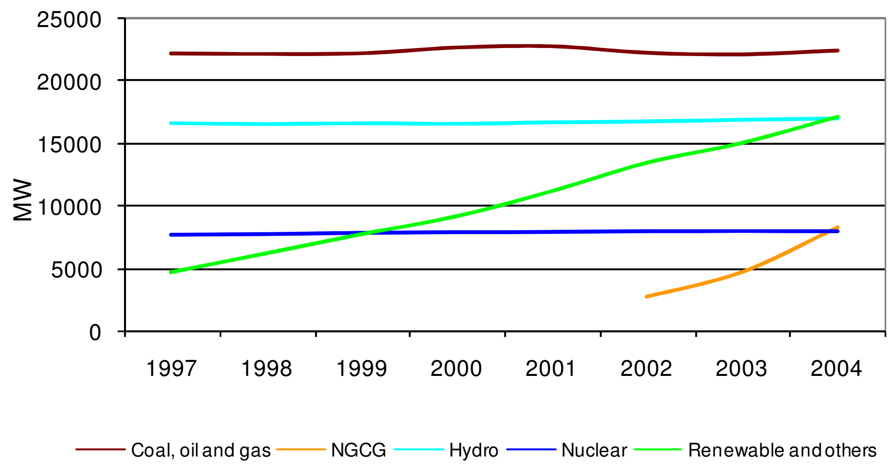
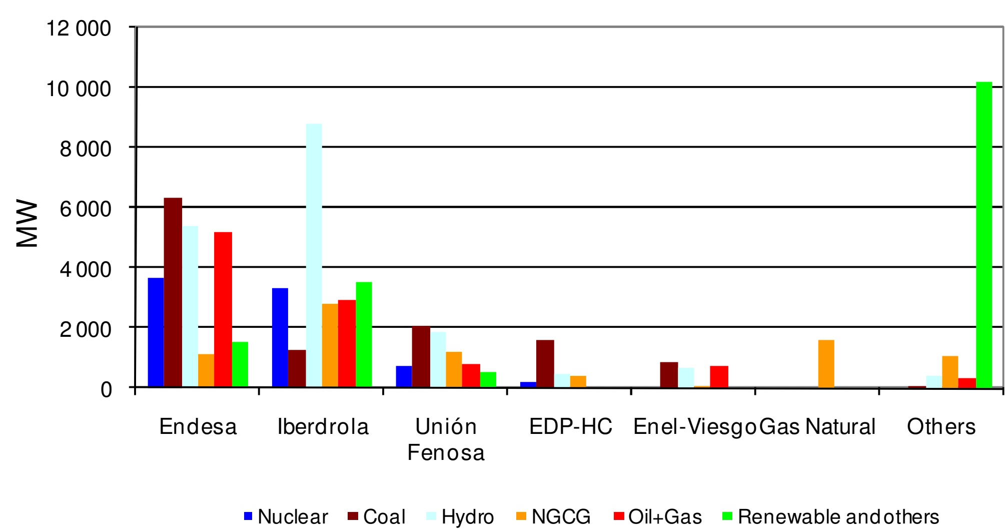


Figure 2 shows the installed capacity in conventional technologies, without renewables, in Spain in 2004, by company.

Figure 2- Installed capacity in Spain in 2004

(Conventional technology)



In 2004 the Iberian electricity market was an oligopoly, quite concentrated - almost a duopoly - where Endesa and Iberdrola were the two main companies. This is why the paper focuses on those two producers.

The fact that the Iberian electricity market was nearly an oligopoly with two main producers might lead to practising market power. Each hour, each seller (producer or seller) bids the amounts and prices of the energy he is offering to sell (at) and each buyer (trader, consumer or distributer) bids the amounts and prices he wants to buy (at). Those moves are repeated indefinitely. For instance, a Bertrand's game with two players results in competitive equilibrium when there's only one move, but it would turn into a tacit collusion, with non-cooperative strategies, in a super-game case. Any tacit collusion is more or less stable depending on any changes on structural factors, such as the CTC. As various authors have shown, CTCs gave producers the possibility of price dumping (see, Fabra and Crampes, 2004).

The change in CTCs weight, as well as others changes in structural factors, can influence the system marginal price in the medium and long term. The model which contains inter-annual data has to include cost factors and any variables which highlight possible structural changes.

2 Methods

2.1 The way the issues were handled

A descriptive approach was developed in order to better understand Endesa's and Iberdrola's behaviour in the Spanish wholesale market. This approach is based on the analysis of the correlation between the system marginal price, as a dependent variable, and the demand, the energy supplied every hour (by company and by technology) and factors which change in the medium and long term, as independent variables. The econometric analysis is completed with an endogeneity study, which highlights possible bias in the results and detects some unexpected variable dependency in a competitive market.

2.2 The econometric model

The correlation between the system marginal price and a set of variables is analysed for every Wednesday from May to September (which is the "dry season" chosen to reduce the influence of hydrological factors), between 2001 and 2004. The variables are the amount of energy supplied every hour by Endesa and Iberdrola, by technology, the hourly demand and factors which vary on a monthly or annual basis, such as the costs factor (the price of the fuels, the hydrological conditions) and annual structural changes. The data were grouped into three time-of-day periods:

- Peak hours (11h-14h ; 18h-21h).
- Half-peak hours (08h-10h; 15h-17h; 22h-23h).
- Off-peak hours (00h-07h).

Thus, 672 observations were obtained for each period. The model used is defined as follows:

$$P_{tfe} = \beta_s Q_{ts} + \sum_k \beta_{Ek} QE_{tk} + \sum_k \beta_{Ik} QI_{tk} + \beta_{oil} C_{tmoil} + \beta_{coal} C_{t(m-3)coal} + \beta_H H_t + \sum_{i=2002}^{i=2004} \beta_D D_i \qquad (15)$$

For the short term time level, the main independent variables correspond to the amounts bid and matched by technology, *k*, per hour, in MWh, contained by unit groups whose main shareholder[10] is Endesa or Iberdrola (oil/gas units, natural gas combined cycle units, steam coal units, nuclear units, hydro units): QE_{tk} and QI_{tk}. Those variables rely on the companies' short term strategies, plus other factors.

For the medium term and short term analysis, in addition to those variables, the following independent variables were included in the daily market which are linked to the cost factors: the monthly average oil prices (C_{tmoil}), the monthly average coal prices ($C_{t(m-3)coal}$), the hydrological conditions (H_t). Fuel costs are linked to the companies' purchase policies. Most of the time, fuel is purchased irregularly for consumption in the short or medium term. A previous econometric[11] analysis pointed out that there is a relationship between the Spanish electricity market price and the fuel's

[10] The Spanish nuclear power stations have generally got more than one owner.
[11] Through a simple OLS econometric model.

monthly average price for the current month, in the oil case, and for 3 months lag, in the coal case. Dummy variables were introduced in order to point out any impact on the system marginal price of possible annual structural change in during the analyzed period: D_i. It should be noted that the correlation of the variables was analyzed beforehand and no correlation between independent variables was found.

First of all[12], the endogeneity between the independent variables, including amounts supplied by technologies, and the system marginal price, is tested. The endogeneity bias was eliminated through the method of instrumental variables. Instrumental variables have been chosen, bearing in mind that they have to be correlated to the endogenous variables but cannot be correlated to the residuals. In relation to the variable for the amounts supplied, the instrumental variables have been chosen taking into account that strategies can be re-arranged by sets of hours: the bid quantities each hour should follow a similar pattern to that of some hours around this particular hour on the previous day, i.e, the Wednesday before.

For independent variables, the endogeneity between the system marginal price and those variables can be explained by the omission of explanatory variables. Thus, the instrumental variable can be independent of the daily cycle. Since the models are based on temporal series, the instrumental variables chosen are linked to the variable through a determinate period lag, which has been chosen in such a way as to guarantee the trade-off between being large enough to be independent of the daily cycle and being small enough to lose the smallest degree of freedom possible. The choice of the instrumental variables is a recursive process: each Sargan's statistic of the model obtained from the set of instrumental variables is compared and the final set of instrumental variables chosen is the set which provides the highest Sargan's statistic (asymptotically distributed as χ^2). For that purpose, more than 400 different sets of instrumental variables were tested. The selected instrumental variables for each hourly variable are more or less equal to 24 hours lag. For the remaining variables, the instrumental

[12] It is important to emphasize that the analysis of the variables' correlation was carried out previously and no correlation between independent variables was found. One-way analysis of variance for the 4 periods (2001, 2002, 2003 and 2004) was also undertaken to test the null hypothesis that the means are different and that the model is stationary. This hypothesis was rejected.

variables selected are also the respective variable, but with 36 hours lag.

Less significant variables are withdrawn from the initial model in order to define a model composed of significant variables, which better explains the price evolution. To avoid any misspecification problem caused by the stepwise variable selection, the process was carried out cautiously: only variables with P values greater than 0.65 were eliminated at each step and a joint test of zero restrictions on the coefficients of deleted variables was applied. During this selection process, Sargan's statistic is used as a general test of misspecification of the models obtained. Any variable is withdrawn if, and only if, Wald's statistic of the joint test is lower than in the previous case and, at the same time, the new model presents a higher Sargan's statistic than before.

Then, for each time-of-day period, the models are chosen, as follows:

1. A linear regression model was used, through the ordinary least squares method, with all the dependent variables;
2. The unit root is tested to check for the model's stationarity[13];
3. The endogeneity of all the independent variables has been tested, through the Wu-Hausman T_2 statistic;
4. The endogeneity problem is removed, through the method of instrumental variables.
5. Sargan's statistic is used as a general test of misspecification of the models and of the instrumental variables.
6. Functional form[14], heteroscedasticity and residual autocorrelation were tested.
7. Variables are withdrawn from the initial model only in rigorous conditions, that is, if:
    a. *t's* statistics is less than 0.5.
    b. The Wald's statistic obtained from the joint test of zero restrictions on the coefficients of deleted variables is lower than in the previous case.
    c. The new model doesn't present a *p* value for the Sargan's statistic lower than in the

[13] The Augmented Dickey-Fuller test showed that the null hypothesis of a unit root was rejected for each model
[14] Data characteristics compel the assumption of a linear function and prevent the assumption of a log function.

previous model.

3 Off-peak hours results

3.1 Endogeneity analysis

Table 1 presents the endogeneity analysis results (tested through the Wu-Hausman's T_2 statistic). The dependent variables that are probably endogenous are marked with orange, at the 25.0% level of significance[15]. Endogenous variables are: the total quantities supplied (QT_t), which also represent the demand; quantities supplied by Endesa's oil (QE_{toil}) and coal units (QE_{tcoal}) and by Iberdrola's coal (QI_{tcoal}), nuclear ($QI_{tnuclear}$), and hydro units (QI_{thydro}); the hydrological conditions (H_t); the monthly average coal prices ($C_{t(m-3)coal}$); 2002 and 2004 dummy variables (D_{t2002} and D_{t2004}). At off-peak hours any kind of technology can define the system marginal prices, therefore, as for the total quantities supplied case, the fact that quantities supplied by hydro, oil, coal and even nuclear units are endogenous is due to the expectable simultaneity between those variables and the system marginal prices.

[15] For the purpose of decreasing type II error

Table 1

Endogeneity analysis - Off-peak hours

Residual regressor	T-Ratio [Prob]
Residual QT_t	-4.823[0.000]
Residual QE_{tgn}	0.359[0.720]
Residual QI_{tgn}	-0.00766[0.994]
Residual QE_{toil}	-2.481[0.013]
Residual QI_{toil}	0.512[0.609]
Residual Q_{Etcoal}	2.499[0.013]
Residual QI_{tcoal}	1.168[0.243]
Residual $QE_{tnuclear}$	0.545[0.586]
Residual $QI_{tnuclear}$	1.390[0.165]
Residual QE_{thydro}	0.034[0.973]
Residual QI_{thydro}	-1.469[0.142]
Residual H_t	-5.423[0.000]
Residual C_{tmoil}	-0.243[0.808]
Residual $C_{t(m-3)coal}$	-1.560[0.119]
Residual D_{t2002}	-2.403[0.017]
Residual D_{t2003}	0.536[0.592]
Residual D_{t2004}	1.785[0.075]

3.2 The model

The instrumental variables used to remove the endogeneity problem are:

- Hourly quantities supplied by Endesa's oil and coal units with 23, 24, 25 and 26 hours lag.
- Hourly quantities supplied by Iberdrola's nuclear, coal and hydro units with 23, 24, 25 and 26 hours lag.
- Total quantities supplied with 23, 24, 25 and 26 hours lag.
- Hydrological conditions with 36 hours lag.
- Monthly average coal price with 36 hours lag.
- 2002's and 2004's dummy variables with 36 hours lag.

Table 2 shows the model's main statistics and tests performed. GR^2 is the equivalent of R^2 for the methodology of the instrumental variables. GR^2 is equal to 0.43. As at the 5% level of significance, there is heteroscedasticity, therefore a Newey-West heteroscedasticity and autocorrelation adjusted variance-covariance matrix is performed.

The model and instrumental variables are well-specified, taking into account Sargan's statistic, which has a extremely high *p* value: 0.99. However, there's no variable which is significant at 5% level of significance, as shown in Table 3.

Table 2

Main statistics - Initial models - Off-peak hours

GR^2	0.43
Sargan's Statistic (Chi-squared distribution) [Prob.]	2.236[0.99]
Newey-West heteroscedasticity and autocorrelation consistent estimates of the variance-covariance matrix of the parameters estimate	Yes: lag = 2
Value of the last Wald statistic for the variable deletion test	-

Table 3

Initial models - Off-peak hours

Regressors	Coeficients	Standard errors	T-ratios
Constant	-11.651	21.6988	-0,53696[0,591]
QT_t	0.000531	0.000486	0,903[0,367]
QE_{tgn}	0.00108	0.0029	0,322[0,747]
QI_{tgn}	-0.0019	0.00206	-0,726[0,468]
QE_{toil}	0.000326	0.0022	0,134[0,893]
QI_{toil}	-0.00162	0.00173	-1,059[0,290]
QE_{tcoal}	0.000083	0.000932	0,0680[0,946]
QI_{tcoal}	-0.001149	0.0013	-0,577[0,564]
$QE_{tnuclear}$	-0.000245	0.00117	-0,147[0,883]
$QI_{tnuclear}$	-0.0024	0.0023	-0,914[0,361]
QE_{thydro}	-0.000432	0.0006	-0,584[0,559]
QI_{thydro}	0.000131	0.00075	0,171[0,864]
H_t	-2.3448	3.026	-0,688[0,492]
C_{tmoil}	0.18422	0.515	0,290[0,772]
$C_{t(m-3)coal}$	0.20367	0.134	1,43[0,154]
D_{t2002}	3.12	2.553	0,980[0,327]
D_{t2003}	3.2803	4.893	0,513[0,608]
D_{t2004}	-3.2994	1.564	-1,739[0,083]

Table 4 presents the final model that has been selected for off-peak hours. At the 5% level of significance, the variables which explain the system marginal price evolution at off-peak hours are: total quantities supplied (QT_t); coal prices ($C_{t(m-3)coal}$); 2004 dummy variable (D_{t2004}), which is negatively correlated to the system marginal price.

Table 4

Chosen model - Off-peak hours

Regressors	Coeficients	Standard errors	T-ratios
Constant	-15.778	15.5713	-1.013[0.311]
QT_t	0.001	0.0002	3.452[0.001]
QE_{tgn}	0.001	0.0010	0.879[0.380]
QI_{tgn}	-0.002	0.0018	-1.087[0.277]
QIt_{oil}	-0.002	0.0015	-1.054[0.292]
QI_{tcoal}	-0.001	0.0012	-0.939[0.348]
$QI_{tnuclear}$	-0.002	0.0017	-1.161[0.246]
QE_{thydro}	0.000	0.0005	-0.817[0.414]
H_t	-1.640	1.5804	-1.038[0.300]
C_{tmoil}	0.221	0.4203	0.526[0.599]
$C_{t(m-3)coal}$	0.210	0.0964	2.177[0.030]
D_{t2002}	3.455	2.1637	1.5967[0.111]
D_{t2003}	3.736	3.9596	0.944[0.346]
D_{t2004}	-3.473	1.3263	-2.618[0.009]

Table 5 shows the main statistics and the tests performed for the chosen model. GR^2 is equal to 0.43. At the 5% level of significance, there is heteroscedasticity and residual autocorrelation, therefore a Newey-West heteroscedasticity and autocorrelation adjusted variance-covariance matrix is performed. The last Wald statistic for the variable deletion test has an extremely high *p* value: 0.99.

The model and instrumental variables are well specified, taking into account the Sargan's statistic, which has the maximum *p* value: 1.00.

Table 5

Main statistics - Chosen model - Off-peak hours

GR^2	0.43
Sargan's Statistic (Chi-squared distribution) [Prob.]	2.625[1.00]
Newey-West heteroscedasticity and autocorrelation consistent estimates of the variance-covariance matrix of the parameters estimate	Yes: lag = 2
Value of the last Wald statistic for the variable deletion test	0.115 [0.99]

Thus, for off-peak hour periods, the main results are:

- Quantities supplied by Endesa's coal and oil units and by Iberdrola's nuclear, coal and hydro units are endogenous variables, which is expectable, since at off-peak hours any of these units can define the system marginal prices.
- There are no quantities supplied by any kind of unit. This explains the system marginal price evolution.
- Overall amounts supplied are positively correlated to the clearing prices.
- Monthly coal prices, 3 months lagged, are positively correlated to the clearing prices.
- System marginal prices have presented a different evolution in 2004, which can explain a fall in prices at off-peak hours.

4 Half-peak hours results

4.1 Endogeneity analysis

Table 6 presents the endogeneity analysis results (tested through Wu-Hausman's T_2 statistic). All the variables are endogenous, at the 25.0% level of significance[16], except for: quantities supplied by Iberdrola's natural gas combined cycle units, and nuclear units (QI_{tgn} and $QI_{tnuclear}$); the price of oil

[16] For the purpose of decreasing type II error

(Ct_{moil}). The fact that quantities supplied by peak load units (oil and natural gas combined cycle units) are endogenous variables is due to the expectable simultaneity between those variables and the system marginal prices. The fact that quantities supplied by base load units (Endesa's coal and nuclear units and Iberdrola's coal units) are endogenous variables is probably due to expectation about the system marginal prices. This would be confirmed if the variables are significant and inversely correlated with the system marginal price evolution. It should be stressed that all quantities supplied by Endesa's unit are endogenous variables.

Table 6

Endogeneity analysis – Half-peak hours

Residual regressor	T-Ratio [Prob]
Residual QT_t	1.342[0.180]
Residual QE_{tgn}	-5.148[0.000]
Residual QI_{tgn}	-1.104[0.270]
Residual QE_{toil}	-7.130[0.000]
Residual QI_{toil}	5.675[0.000]
Residual Q_{Etcoal}	2.108[0.035]
Residual QI_{tcoal}	2.119[0.034]
Residual $QE_{tnuclear}$	3.453[0.001]
Residual $QI_{tnuclear}$	0.128[0.898]
Residual QE_{thydro}	-2.944[0.003]
Residual QI_{thydro}	4.186[0.000]
Residual H_t	-1.684[0.093]
Residual C_{tmoil}	0.5402[0.589]
Residual $C_{t(m-3)coal}$	-2.262[0.024]
Residual D_{t2002}	-2.294[0.022]
Residual D_{t2003}	1.627[0.104]
Residual D_{t2004}	3.084[0.002]

4.2 The model

The instrumental variables used to remove the endogeneity problem are:

- Hourly quantities supplied by Endesa's oil, natural gas combined cycle, coal, nuclear and hydro units with 24, 25 and 26 hours lag.
- Hourly quantities supplied by Iberdola's oil, coal and hydro units with 24, 25 and 26 hours lag.
- Total quantities supplied with 24, 25 and 26 hours lag.

- Hydrological conditions with 36 hours lag.
- Monthly average coal prices with 36 hours lag.
- 2002, 2003 and 2004 dummy variables with 36 hours lag.

Table 7 shows the model main statistics and the tests performed. GR^2 is equal to 0.38. At the 5% level of significance, there is residual autocorrelation, therefore a Newey-West heteroscedasticity and autocorrelation adjusted variance-covariance matrix is performed. The model and instrumental variables are well specified, taking into account the Sargan's statistic, which has the maximum *p* value: 1.00.

Table 7

Main statistics - Initial models - Half-peak hours

GR^2	0.38
Sargan's Statistic (Chi-squared distribution) [Prob.]	2.94[1.00]
Newey-West heteroscedasticity and autocorrelation consistent estimates of the variance-covariance matrix of the parameters estimate	Yes: lag = 2
Value of the last Wald statistic for the variable deletion test	-

Many variables are significant at 5% level of significance, as shown in Table 8: QT_t, Q_{Etcoal} and $Q_{Etnuclear}$.

Table 8

Initial models - Half-peak hours

Regressors	Coeficients	Standard errors	T-ratios
Constant	2.996	8.598	0.348[0.728]
QT_t	0.001	0.000	2.213[0.027]
QE_{tgn}	0.000	0.001	0.068[0.946]
QI_{tgn}	-0.001	0.001	-1.567[0.118]
QE_{toil}	0.001	0.001	1.222[0.222]
QI_{toil}	-0.001	0.001	-1.225[0.221]
QE_{tcoal}	-0.001	0.000	-2.061[0.040]
QI_{tcoal}	0.000	0.001	-0.664[0.507]
$QE_{tnuclear}$	-0.002	0.001	-2.050[0.041]
$QI_{tnuclear}$	-0.001	0.001	-1.795[0.073]
QE_{thydro}	0.000	0.000	-0.400[0.689]
QI_{thydro}	-0.001	0.000	-1.694[0.091]
H_t	-0.886	1.031	-0.859[0.391]
C_{tmoil}	0.102	0.144	0.709[0.479]
$C_{t(m-3)coal}$	0.038	0.123	0.305[0.760]
D_{t2002}	0.347	1.393	0.249[0.804]
D_{t2003}	-1.474	1.647	-0.895[0.371]
D_{t2004}	-3.345	2.055	-1.628[0.104]

Table 9 shows the main statistics and the tests performed for the chosen model. GR^2 is equal to 0.38. At the 5% level of significance, there is residual autocorrelation, therefore a Newey-West heteroscedasticity and autocorrelation adjusted variance-covariance matrix is performed. The last Wald statistic for the variable deletion test has an extremely high *p* value: 0.98.

The model and instrumental variables are well-specified, taking into account the Sargan's statistic, which has, like the initial model, a maximum *p* value: 1.00.

Table 9

Main statistics - Chosen model - Half-peak hours

GR^2	0.38
Sargan's Statistic (Chi-squared distribution) [Prob.]	2.97[1.00]
Newey-West heteroscedasticity and autocorrelation consistent estimates of the variance-covariance matrrix of the parameters estimate	Yes: lag = 2
Value of the last Wald statistic for the variable deletion test	0.167[0.98]

Table 10 presents the final model that has been selected for half-peak hours. At 0.5% level of significance, the variables which explain the system marginal price evolution at half-peak hours are: total quantities supplied (QT_t) and quantities supplied by Endesa's oil units (QE_{toil}), which are positively correlated to system marginal prices; quantities supplied by Endesa's coal units (QE_{tcoal}) and quantities supplied by Iberdrola's nuclear units ($QI_{tnuclear}$), which are negatively correlated to system marginal prices; 2004 dummy variable (D_{t2004}), which is negatively correlated to the system marginal price.

Table 10

Chosen model - Half-peak hours

Regressors	Coeficients	Standard errors	T-ratios
Constant	4.4204	4.9469	0.894[0.372]
QT_t	0.0005	0.0001	3.127[0.002]
QE_{tgn}	0.0000	0.0007	0.003[0.998]
QI_{tgn}	-0.0010	0.0007	-1.416[0.157]
QE_{toil}	0.0018	0.0008	2.418[0.016]
QIt_{oil}	-0.0011	0.0010	-1.083[0.279]
QE_{tcoal}	-0.0009	0.0004	-2.166[0.031]
$QE_{tnuclear}$	-0.0004	0.0007	-0.537[0.592]
$QI_{tnuclear}$	-0.0017	0.0007	-2.328[0.020]
QI_{thydro}	-0.0009	0.0006	-1.423[0.155]
H_t	-0.6940	0.9078	-0.764[0.445]
C_{tmoil}	0.1317	0.1107	1.190[0.235]
D_{t2003}	-1.6954	0.9528	-1.779[0.076]
D_{t2004}	-2.7707	1.0232	-2.708[0.007]

Thus, for half-peak hour periods, the main results are:

- The quantities supplied by base load units (Endesa's coal and nuclear units and Iberdrola's coal units) are endogenous variables, which may be due to expectations about the system marginal prices[17].
- Demand has a significant influence on price increases, as in the off-peak hours period.
- Quantity produced by units influences price according to their variable costs:
  - The quantity produced by the most expensive units, the oil units (Endesa owned), influence the system marginal price increases, the quantity produced by base load units, nuclear (Iberdrola owned) and coal (Endesa owned) influence the system marginal price falls. The fact that the quantity produced by base load units influences the system marginal decrease can also be explained by the UPA market characteristic: capacity withdrawing increases the system marginal price. This conclusion is reinforced in Endesa's coal unit case, since this variable is endogenous.
- The year 2004 influenced the system marginal price decrease at half-peak hours.

5 Peak-hours results

5.1 Endogeneity analysis

Table 11 presents the endogeneity analysis results. All the variables are endogenous, at the 25.0% level of significance[18], except for: quantities supplied by Iberdrola's nuclear units ($QI_{tnuclear}$); quantities supplied by Endesa's coal and nuclear units (QE_{tcoal} and $QI_{tnuclear}$); the hydological conditions (H_t); 2003 dummy variable (D_{t2003}). The fact that quantities supplied by peak load units (oil and natural gas combined cycle units) are endogenous variables is due to the expectable simultaneity between those variables and the system marginal prices. The quantity supplied by Iberdrola's coal units (QI_{tcoal}) is the only variable related to base load units, which is endogenous. The fact that the quantity supplied by those base load units is an endogenous variable may be due to expectations about the system marginal

[17] This assumption can be risky, since in some, rare, cases at half-peak hours this technology defines the system marginal price.
[18] For the purpose of decreasing type II error

prices.

This would be confirmed if the variable is significant and inversely correlated with the system marginal price evolution.

Table 11

Endogeneity analysis – Peak hours

Residual regressor	T-Ratio [Prob]
Residual QT_t	1.630[0.104]
Residual QE_{tgn}	-4.309[0.000]
Residual QI_{tgn}	-2.291[0.022]
Residual QE_{toil}	-11.534[0.000]
Residual QI_{toil}	7.590[0.000]
Residual Q_{Etcoal}	0.00691[0.994]
Residual QI_{tcoal}	4.309[0.000]
Residual $QE_{tnuclear}$	0.799[0.425]
Residual $QI_{tnuclear}$	-0.256[0.798]
Residual QE_{thydro}	-4.258[0.000]
Residual QI_{thydro}	6.652[0.000]
Residual H_t	0.656[0.512]
Residual C_{tmoil}	4.486[0.000]
Residual $C_{t(m-3)coal}$	-3.050[0.002]
Residual D_{t2002}	-3.643[0.000]
Residual D_{t2003}	0.545[0.586]
Residual D_{t2004}	2.570[0.010]

5.2 The model

The instrumental variables used to remove the endogeneity problem are:

- Hourly quantities supplied by Endesa's oil, natural gas combined cycle, and hydro units with 23, 24, 25 and 26 hours lag.
- Hourly quantities supplied by Iberdola's oil, natural gas combined cycle, coal and hydro units with 23, 24, 25 and 26 hours lag.
- Hourly demand with 23, 24, 25 and 26 hours lag.
- Hydrological conditions with 36 hours lag.
- Monthly average oil and coal prices with 36 hours lag.

- 2002’s and 2004’s dummy variables with 36 hours lag.

Table 12 shows the model’s main statistics and the tests performed. GR^2 is equal to 0.31. At the 5% level of significance, there is residual autocorrelation, therefore a Newey-West heteroscedasticity and autocorrelation adjusted variance-covariance matrix is performed. The model and instrumental variables are well-specified, taking into account the Sargan’s statistic, which presents the maximum *p* value: 1.00.

Table 12

Main statistics - Initial models - Peak hours

GR^2	0.31
Sargan's Statistic (Chi-squared distribution) [Prob.]	3.72[1.00]
Newey-West heteroscedasticity and autocorrelation consistent estimates of the variance-covariance matrrix of the parameters estimate	Yes: lag = 2
Value of the last Wald statistic for the variable deletion test	-

There is no variable which is significant at the 5% level of significance, as shown in Table 13.

Table 13

Initial models - Peak hours

Regressors	Coeficients	Standard errors	T-ratios
Constant	-4.5764	10.0177	-0.457[0.648]
QT_t	-0.0001	0.0005	-0.184[0.854]
QE_{tgn}	0.0009	0.0014	0.638[0.523]
QI_{tgn}	0.0011	0.0013	0.838[0.402]
QE_{toil}	0.0018	0.0014	1.266[0.206]
QIt_{oil}	0.0019	0.0018	1.097[0.273]
QE_{tcoal}	0.0003	0.0008	0.373[0.709]
QI_{tcoal}	0.0001	0.0011	0.0735[0.941]
$QE_{tnuclear}$	0.0009	0.0014	0.654[0.513]
$QI_{tnuclear}$	0.0000	0.0011	-0.0399[0.968]
QE_{thydro}	0.0010	0.0009	1.190[0.234]
QI_{thydro}	-0.0003	0.0005	-0.568[0.570]
H_t	1.6400	1.5546	1.055[0.292]
C_{tmoil}	0.2437	0.1591	1.53[0.126]
$C_{t(m-3)coal}$	-0.0747	0.1588	-0.471[0.638]
D_{t2002}	-0.8225	2.2852	-0.360[0.719]
D_{t2003}	-1.3692	2.8683	-0.477[0.633]
D_{t2004}	-1.2531	2.3615	-0.530[0.596]

Table 14 shows the main statistics and the tests performed for the chosen model. GR^2 is equal to 0.31. At the 5% level of significance, there is residual autocorrelation and heteroscedasticity, therefore a Newey-West heteroscedasticity and autocorrelation adjusted variance-covariance matrix is performed. The last Wald statistic for the variable deletion test presents an extremely high *p* value: 0.99.

The model and instrumental variables are well-specified, taking into account the Sargan's statistic, which presents, like the initial model, the maximum *p* value: 1.00.

Table 14

Main statistics - Chosen model - Peak hours

GR^2	0.31
Sargan's Statistic (Chi-squared distribution) [Prob.]	5.37[1.00]
Newey-West heteroscedasticity and autocorrelation consistent estimates of the variance-covariance matrrix of the parameters estimate	Yes: lag = 2
Value of the last Wald statistic for the variable deletion test	0.71[0.99]

Table 15 presents the final model that has been selected for peak hours. At the 5% level of significance, the variables which explain the system marginal price evolution at peak hours are: quantities supplied by Endesa's oil and hydro units (QE_{toil} and QE_{thydro}); quantities supplied by Ibedrola's oil units (QI_{toil}); monthly average oil prices (C_{tmoill}); 2004 dummy variable (D_{t2004}), which is negatively correlated to the system marginal price.

Table 15

Chosen model - Peak hours

Regressors	Coeficients	Standard errors	T-ratios
Constant	-8.2844	4.9704	-1.667[0.096]
QE_{tgn}	0.0010	0.0007	1.530[0.126]
QI_{tgn}	0.0006	0.0005	1.112[0.266]
QEt_{oil}	0.0015	0.0006	2.304[0.022]
QIt_{oil}	0.0016	0.0005	2.983[0.003]
QE_{tcoal}	0.0003	0.0005	0.485[0.628]
$QE_{tnuclear}$	0.0007	0.0008	0.820[0.412]
QE_{thydro}	0.0008	0.0003	2.626[0.009]
QI_{thydro}	-0.0004	0.0003	-1.433[0.152]
H_t	1.6536	1.1569	1.429[0.153]
C_{tmoil}	0.2258	0.1113	2.030[0.043]
D_{t2004}	-2.0028	0.8885	-2.254[0.025]

Thus, for peak hours periods, the main results are:

- Quantity produced by Endesa's coal units' is an endogenous variable, but significantly it does not explain the system marginal price evolution. Therefore, any suspicion about anticompetitive behaviour, based on the endogeneity analysis cannot be sustained with certainty.

- Quantity produced by oil units, which determines the system marginal price increase.
- Quantity produced by Endesa's hydro units also determines the system marginal price increase.
- Demand is not a significant variable for the system marginal price determination.
- Monthly oil prices are positively correlated to the system marginal prices.
- 2004 is correlated to the system marginal decrease.

6 Conclusions

Trying to show to what extent the Spanish, actually Iberian, UPA market design, can lead to anti-competitive practices, multi variable models based on bid quantities strategies have been developed which describe the market price evolution for every Wednesday from May to September, between 2001 and 2004. In addition to highlighting those units whose quantity strategies influenced price evolution for each period of the day, this descriptive approach can provide some clues about possible anti-competitive strategies, i.e. whether quantities supplied by base load units are endogenous and, simultaneously, whether these quantities are inversely correlated with prices, i.e., the decrease in quantities supplied by a base load unit influences price increase.

Before drawing any conclusion about possible anti-competitive behaviour from the multi-variable models, one has to confirm that the main multivariable results do not conflict with the common knowledge on the electricity spot markets.

The results obtained for the analysed period are consistent with the electricity wholesale market characteristics:

- At off-peak hours, quantities supplied are not significant variables.
- At half-peak hours, the quantity supplied by Endesa's oil units is the only variable which explained the system marginal price increase on an hourly basis. Oil technology is the

dearest/most marginal technology in the Spanish wholesale market.

- At half-peak hours, there is an inverse and significant correlation between quantities supplied by base load units (Endesa's coal units and Iberdrola's nuclear units) and the system marginal prices.
- At peak hours, oil units and hydro units, which are also marginal units in the summer, explain the system marginal price increase on an hourly basis.
- The significance of demand as an explaining variable of the system marginal price evolution decreases from off-peak hours to half peak hours, and is not more significant at that period of the day. This fact is not surprising taking into account that at peak hours price elasticity of demand is very low.

Therefore, the models showed that during the analysed period the system marginal price evolution can be explained through the quantities supplied at half-peak hours and at peak hours. The fact that the quantities did not influence the prices at off-peak hours is not surprising, considering that the load diagram is almost flat at this period of the day. The results also showed that at off-peak hours demand was the only significant hourly variable which explained the system marginal price evolution.

In relation to the endogeneity analysis, which stresses any possible anti-competitive analysis, the following results were obtained:

- At half-peak hours, the quantity supplied by Endesa's nuclear units and by Iberdrola's and Endesa's coal units are the variables associated with infra-marginal unit supplies, and these are endogenous.
- At peak-hours, the quantity supplied by Iberdrola's coal units is the variable associated with infra-marginal unit supplies, and this is endogenous.

However, only once, at half-peak hours for quantities supplied by Endesa's coal units, a variable is simultaneously inversely and significantly correlated to the system marginal price, and is endogenous. This does not reject the evidence shown: even the infra-marginal producers' bid on the Spanish/Iberian

UPA electricity market can include expectations about the market clearing prices. Those expectations can reflect market strategies, such as the raising of the system marginal price through the capacity withdrawal from base load units. Those strategies are naturally developed in the present case, because:

- Bids in a spot market are just like a supergame, where players have a reasonable knowledge of the competitors supply functions (see for example, Puller (2007)).
- As this paper has stressed, the supply curve is concave on marginal costs.
- The market is almost inelastic at certain periods of the day, as the present work has shown for the analysed period.
- The main Iberian companies own the base load and peak load units.

In parallel with the main objective of this work and its related results, other interesting, if expectable, results have been obtained. For example, the selected models show that some production factors, which vary on a monthly basis, are significant variables, which explain the system marginal price increase: coal prices at off-peak hours and oil prices at peak hours. Finally, the results also show that 2004, *per se*, influenced the system marginal price fall in every period of the day. It has to be remembered that in the summer of 2004 Iberdrola claimed that Endesa was leading anti-competitive practices in the daily market, specifically through price dumping, taking advantage of the market design. However, the present study cannot surely confirm those accusations, only 2004's particularities[19]. The application of structural models may help to prove it.

In short, once the problem of endogeneity is properly addressed, the use of a descriptive price model based on quantities boosted the arguments to those who advocate that the UPA, like the PABA, encourages price manipulation by companies, in a way that could, naively or not, be considered anti-competitive. As has already been mentioned, UPA was initially linked to the belief in the proper functioning of markets. The interest of this paper is that it has shown that the UPA, too, like the PABA, definitely requires continuous monitoring on the part of the regulators.

[19] Even so, as Fabra and Crampes (Fabra and Crampes, 2004) stated: "a firm will optimally operate at prices below marginal costs whenever its CTC share exceeds its market share, and at prices above marginal costs otherwise". As the weight of CTC decreased a lot in certain companies in 2004, notably Iberdrola, the door was opened to any kind of price war.

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