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# Measuring the Simultaneous Quantity Game in OMEL Spot Electricity Market

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**ABSTRACT**: In the electricity spot market the various competitive levels, as well as their subsequent changes in the market equilibrium, are justified by the simultaneous quantity game between electricity generators. It is expected that the dominant market players employ differentiated strategic behaviours, thus, permitting the quantification of such differentiated effects on the use of market power. The various competitive levels, as well as their subsequent changes in the market equilibrium, are justified by the simultaneous quantity game. The results show that the quantities purchased in the spot market for sale in open market influence prices, i.e., when there is an imbalance in the estimated long-term relationship, prices themselves move in order to recover the state of equilibrium, which reveals that, in the long-term, the OMEL Price is weakly exogenous to the cointegration vector, whereas quantities purchased for sale in open market move towards the reestablishment of the long-term equilibrium.

**Keywords**: Market Conduct; Collusion; Electricity Spot Market; Market power.
**JEL Classifications:** D43; L11

## 1. Introduction

Many energy markets, namely within the European electrical energy sector, have undergone various restructuring processes. Such processes have resulted in significant structural and regulatory changes. In the latter half of the 1990s, the Spanish electricity market was an excellent and natural environment for the analysis of the relationship between "market power" and levels of competitive intensity. An important characteristic of the Spanish electricity industry was the strong oligopolistic influence of the following companies: Endesa, Iberdrola, Unión Fenosa, Hidrocantábrico and Viesgo. These companies exert a strong influence over the structure of the spot energy market. By taking this particularity into account, it is possible to concentrate on the behaviour of this target market, focusing on a specific market structure where companies must make production decisions facing the pressure of market entry by competitors.

The restructuring of the energy market has resulted in changes that have altered the design of the entire European electrical network. These alterations have also consolidated liberalisation processes within energy markets. Reforms in the Spanish electricity market, as well as in other European countries, consisted of the transition from a vertically integrated system, including production, transportation, distribution and commercialisation, to a system with divisions based on the largest areas of activity, including regulated non-competitive activities. The purpose of this separation was to increase economic efficiency through price adjustment (a short-term goal), and to improve investment decisions by optimizing the risks associated to such investments (a long-term goal).

The market power of the principal players of the Spanish electricity industry emerges from their ability in setting prices within the wholesale market.

Endesa and Iberdrola's capacity to set marginal prices within the wholesale market cannot be solely explained by their capabilities for energy production in relation to the global capacity of the Spanish market. The composition of their respective production plants and production *mix* must also be taken into consideration. Therefore, the setting of supply prices within the pool, for the different hourly periods, is conditioned by the differences between production technologies used by the plants that generate the power installed in the system.

Smaller electricity production companies and third party operators when considered together do not possess the conditions to set prices in the majority of hourly periods. In addition to Endesa and Iberdrola, other Spanish operators, namely Unión Fenosa and Hidrocantábrico, obtained prices set by the dominant operators in the majority of hourly periods (Kühn and Machado, 2004). As was previously mentioned, Endesa and Iberdrola set prices in approximately 60% to 80% of offers submitted. Given that quantities offered above the marginal price do not sell in the daily market, other operators, aware of the fact that offers by Endesa and Iberdrola are necessary to satisfy demand during most hourly periods, tend to present bids at zero price since they know that their electricity will be sold at the marginal price set within the pool (and not at the price that the electricity was offered). Consequently, those two major operators may use their important production mix in order to present flexible bids that meet the expectations of supply and demand. On the other hand, small operators, such as Unión Fenosa and Hidrocantábrico, who have a limited production mix, do not have the capacity to present competitive and flexible offers. For these operators, the choice to offer production at zero cost, knowing that Endesa and Iberdrola will claim the highest prices, is the easiest way of selling the highest possible quantity.

Firms being net demanders or net suppliers influence the way market power is exercised (Kühn and Machado, 2004). As Endesa has an incentive to under-produce, in order to raise the price received for the net electricity sold to the market and as Iberdrola has an incentive to reduce the price paid for the inframarginal units purchase from the spot market, Kühn and Machado (2004) suggest Endesa is a net supplier and Iberdrola a net demander.

Vertical integration could also have affected the market power in Spanish spot electricity market of generators. Its effect on bidding was neutralised by the fact that distribution was a regulated activity and consequently distributor profits were not in the objective function of generators (distribution surplus was used for the Costs of Transition to Competition (CTC) payments (Kühn and Machado, 2004; Crampes and Fabra, 2005; Ciarreta and Espinosa, 2010, 2012).

Although incentives for vertically integrated firms to increase or decrease prices could be determined by whether they are net buyers or net sellers, any positive surplus generated by a distribution company was shared among the generators according to percentages given by the CTC rights. Accordingly, all firms behaved as net sellers. As incentives provided by the regulation interferes with the day-ahead market they might result in lower prices than the ones predicted by the profit maximisation behaviour. On the other hand, the CTC payment was dependent on an average pool price lower than 3.606 c€/KWh. Accordingly, the revenues obtained for higher prices were subtracted from future CTC payments if the power producer average price exceed that amount (Ciarreta and Espinosa, 2012). That price cap criteria and adequate regulation provide guidance as to what constitutes anti-competitive practices among market-leading energy providers (Banovac et al., 2009).

Regulatory authorities use market mitigation approaches to reduce the incentives of the producer to exercise market power by withholding output from the wholesale electricity market. While market power in electricity markets has been already researched in the literature, there are hardly any studies analysing the interactions between market power and bidding strategies confronting the absence and the presence of regulation. In other words, this analysis proposes the simultaneous determination of the two decision variables in the resolution of the quantities strategy game. We propose, and empirically validate, the theoretical models with the purpose of assessing the impact of market-power use exercised by Spanish electricity companies throughout their different strategic iterations.

The various competitive levels, as well as their subsequent changes in the market equilibrium, are justified by the simultaneous quantity game between electricity generators. It is expected that the members of the dominant market group (Endesa, Iberdrola and Unión Fenosa) employ differentiated strategic behaviours, thus, permitting the quantification of such differentiated effects on the use of OMEL market power.

The remainder of this paper is organised as follows: the next section reviews the literature on market power briefly outlining the unregulated Spanish electricity market (OMEL). The third section describes data. The fourth section reports the main results. The fifth section draws some concluding observations.

**2. Literature Review**

Most of these studies have mainly focused on short-term decisions, taking existing capacity as given. They show that market power can be more fully exercised when the capacity of rivals is exhausted (Borenstein and Bushnell, 1999; Green and Newberry, 1992; Bushnell, 2003; Joskow and Kahn, 2002). The most controversial assumption is when the incumbent generator pursues its maximum profit taking into account its residual demand function, which relates the price to its electricity output (Ventosa et al., 2005).

When estimating a competitive supply function in terms of marginal cost, Stoft (2002) found that marginal costs pricing suffices to cover the capital cost of investment, because price spikes occur in periods of storages. On the other hand, Crampton and Stoft (2006) and Joskow (2007) reckon that marginal costs should set the competitive prices when the market is characterised by overcapacity.

Wolfram's (1999) study on electricity markets opened the way to rigorous market power analysis. Using direct measures of marginal cost to estimate price cost margins, she found that, as power generators were not taking full advantage of the inelastic demand, prices were closer to marginal cost than market competition models predicted.

The Cournot model (Kelman et al., 2001; Barquin et al., 2003; Coutinho and Oliveira, 2013), the multi-unit auction model (Ausubel and Cramton, 2002; Fabra and Toro, 2005; Fabra, von der Fehr and Harbord, 2002; Wilson, 1979; Wolfram, 1999; García-Díaz and Marín, 2003) and the Supply Function Equilibrium (SFE) (Klemperer and Meyer, 1989; Green and Newbery, 1992; Green, 1996; Baldick et al., 2004; Newberry, 1995) have been used to assess the specific impact on the mitigation of market power on the wholesale electricity market.

The importance of accurately forecasting electricity prices for competitive electricity markets has been studied by Murthy et al. (2014) with a particular emphasis on the Indian electricity markets. Schwarz and Lang (2006), analysing the prices in the German electricity market, found that full prices rose from 2000 until 2005, being allowance prices in 2005 the major price influencers. Moreover, the impact of market power increased and in 2003 influenced the electricity market prices. When comparing the electricity markets of Germany and England and Wales, Zachmann (2007), using a Markov switching model, concluded that the former had a closer relation to marginal costs.

Karahan and Toptas (2013) explored the Turkish electricity sector under a hybrid wholesale mechanism. They found that regulated wholesale prices are more effective in the determination of end-user prices, while unregulated prices might have a price reduction effect in case the free market dominates. Althoug liberalisation and restructuring of the electrical power sector has occurred across Europe, Cerović et al. (2014) defend that investing in renewable energy sources is important for an efficient and sustainable electricity market to take place.

The Spanish wholesale market has been extensively analysed (e.g. García-Díaz and Marín, 2003; Fabra et al., 2002; Kühn and Machado, 2004; Campres and Fabra, 2004; Fabra and Toro, 2005; Furió and Lucia, 2009; Ciarreta and Espinosa, 2010; 2012; Moutinho et al., 2011; Moutinho et al., 2014).

García-Díaz and Marín (2003) showed that the regulatory compensation mechanism of the sunk costs (CTCs) and the coexistence of competition in the electricity spot market are not compatible. Clearly, the study reveals that this situation leads to an increase of the equilibrium price above or below with what would be secured with prices equalled to marginal costs. Such measure enhances the market power exercise and an inadequate allocation of payments among companies in the market can both promote production inefficiency and delay and prevent new competition, which is desired in these energy markets

Fabra et al. (2002) found that equilibrium prices do not decrease with the elasticity of demand. This affects the market whose distortion is due to the exercise of the market power, which is lower with an elastic demand. Regarding the auction equilibrium, they found that when the demand is low, the bids are equal to the marginal cost of the most inefficient agent and only the most efficient will dispatch energy.

Using the supply function with two-step GMM estimation for each market operator (Endesa, Iberdrola, Unión Fenosa, Hidrocantábrico and Viesgo), Kühn and Machado (2004) found that Endesa and Iberdrola exercised market power. The market power exercised by these two major hydroelectric operators has its source in their exogenous variations with an impact on the pool price. They argue the CTC payments to increase or decrease prices could be determined by whether they are net buyers or net sellers in the market. However, Campres and Fabra (2005) argue that any positive surplus generated by a distribution firm was shared among the generators according to percentages given by the incentives rights, so that all firms behaved as net sellers.

Fabra and Toro (2005), analysing the electricity price formation and the collusive behaviour in the Spanish electricity market, concluded that during the price war stage Endesa's mark-up is negative while Iberdrola's is positive. However, during collusion periods both power generators have prices above the marginal costs, i.e., favourable conditions to the market power exercise. These results were however strongly influenced by the impact the CTCs had on the biddings of the firms in the market. They further recognize the existence of periods with low prices that are only sustainable due to collusive strategies or alternatively due to the coexistence of low prices coordinated with mixed price strategies, which lead to multiple price equilibrium.

Furió and Lucia (2009) found that some power generators have an economic incentive to avoid being dispatched in the day-ahead market in order to be called up in the constraints resolution process of the subsequent transmission.

Ciarreta and Espinosa (2010) demonstrate that the larger operators in the day-ahead market are able to increase prices significantly above the competitive benchmark. They provided a measure of market power based on the different bidding behaviour of large and small generators at the specific demand level. Ciarreta and Espinosa (2012), analysing the impact of regulation on electricity wholesale market from 2002 to 2005, they obtained a measure of the gap between optimal price in the absence of regulation and actual prices. They concluded that regulation affected wholesale prices considerably, but became less effective at the end of the sample period which explains the regulatory regime change introduced at the outset of 2006.

## 3. Data Description

The data was obtained from the Spanish wholesale electricity market from January 2002 until June 2007. Data was obtained on a daily bases (average and 24 hourly) from the demand and supply. The data of market price, quantity offered for each agent in the wholesale market and quantity purchased by each agent in wholesale market to sell in open market were retrieved from OMEL data.

We only analysed data from 2002 until 2007, as this period is characterised by a regulatory stability (although we claim that the regulation must have been deeper. In 2006, CTC measures were dropped and virtual power plant auctions were also introduced. The rapid growth of the combined-cycle gas turbines changed the wholesale market once again. As a result we decided not to include data from 2006 onwards, as this would change the period of (weak) regulatory stability we wanted to address.

We adopted the expression of the marginal costs of a power plant given by: $MC_{p,fuel} = f \times cf / LHV \times \eta_p$ (Lagarto et al., 2010), where $MC_p = MC_{p,fuel}$; $MC_p$ is the power plant $p$ marginal cost in Euros/MWh; $MC_{p,fuel}$ is the power plant $p$ marginal cost due to fossil fuel costs in Euros/MWh; $f$ is the fossil fuel price in Euros/ton; $cf$ is a conversion factor equal to 859845 kcal/MWh; $LHV$ is the Lower Heating Value in kcal/ton; and $\eta_p$ is power plant efficiency in %. The different daily periods are significantly conditioned by the differences between the different technologies of production used by the power plants that generate the installed power of the system. We used the daily spot prices of fuel, coal and gas to compute the marginal costs. Data of major fuel sources (oil, coal, gas) were retrieved form the Systems and Energy Section database from a Lisbon-based University.

For the mitigation of market power, with presence of regulatory mechanism (Price cap equal a 36.06 Euros per MWh).

## 4. Empirical Findings

*4.1. Identification of the order of integration of variables based on aggregated market data*

Before beginning with the cointegration of the different variables considered in the theoretical models proposed, we proceeded with the identification of the order of integration of each of the variables presented.

To begin with, the Augmented Dickey–Fuller (ADF) unit root tests (Dickey and Fuller, 1979), shown in Table 1, were implemented, in which:

- ' *POmel* ' is the spot market price: a unit root (first-order integrated processes);
- 'Price Cap': a unit root (first-order integrated processes);
- 'Elasticity' is the price elasticity: a unit root (first-order integrated processes);
- 'Quantity Sold' is the aggregated quantity sold in spot market: stationary process;
- 'Quantity Purchased' is the aggregated quantity purchased in spot market for sale in open market: a unit root (first-order integrated processes).

**Table 1. Unit root test**

| *Variable* | *Levels* | *Number of lags* |
|---|---|---|
| *POmel* | -2.596 | 33 |
| Δ Price Omel | -9.259** | 32 |
| Price Cap+ | -3.344 | 30 |
| Δ Price Cap | -10.627** | 18 |
| Elasticity ( $\varepsilon_p$ ) | -3.054 | 27 |
| Δ Elasticity ( $\Delta\varepsilon_p$ ) | -10.304** | 26 |
| Quantity Purchased ( $Q_{Cv}OM$ ) | -4.824 | 30 |
| Quantity Sold ( $Q_v$ ) | -1.323 | 21 |

** significant at 1%;
\+ Deterministic Trend included in the test.

In a first phase, the cointegration results were analysed based on aggregated market data between *POmel*, price cap, and the potentially explanatory variables of the volatility of those prices: aggregated quantity sold in the pool ( $Q_v$ ), aggregated quantity sold in the pool to be sold in open market ( $Q_{Cv}OM$ ), and the price elasticity of demand ( $\varepsilon_p$ ).

The unit root test results provide mixed evidence as to the order of integration of the variables. The results of Table 1 demonstrate that all variables of the series for *POmel*, price cap and price elasticity of demand ( $\varepsilon_p$ ) contain a unit root in their first difference, and the aggregated quantity purchased in the spot market to be sold in open market ( $Q_{Cv}OM$ ) contains a unit root in the level. The quantity sold in the pool ( $Q_v$ ) is non-stationary.

*4.2. Long-term cointegration results and discussion*

*4.2.1. Relationship between real price ( POmel ), demand elasticity ( $\varepsilon_p$ ), and purchased quantity in the open market ( $Q_{Cv}OM$ ) under the absence of regulation*

In this study, the Johansen (1988) cointegration test is used to assess the presence of cointegration, which is very strong even when dealing with the trend.

According to Table 2, the trace test values are not robust at the usual significant levels for the rejection of the null hypothesis of *r* cointegrating vectors. Accordingly, we could not find evidence of a cointegration vector.

**Table 2. Cointegration trace –Johansen test**

| *H0* | *H1* | *Trace test [prob]* | *Max test [prob]* |
|---|---|---|---|
| *r*=0 | r>0 | 67.334** | 56.536** |
| *r*=1 | r>1 | 10.798 | 8.302 |
| *r*=2 | r>2 | 2.496 | 2.496 |

** significant at 1%.

After estimating an unrestricted VECM model, we successively tested several hypotheses regarding the $\beta$ (cointegration vector) and $\alpha$ (smoothing factors) parameters and concluded that the demand elasticity is the only variable that depends on the cointegration vector, as shown in Model output 1. The remaining variables ( $POmel$ and $Q_{Cv}OM$ ) are weakly exogenous to the cointegration vector.

**Model output 1**

Estimated cointegration vector (VECM) between the demand elasticity, the OMEL price and the quantity purchased in the spot market to be sold in open market.

$$\begin{bmatrix} POmel \\ ElasticityD \\ Q_{Cv}OM \end{bmatrix} = \begin{bmatrix} 0.0 \\ 0.00047 \\ 0.0 \end{bmatrix} \begin{bmatrix} 1 & -390.4 & -0.09188 \end{bmatrix} \begin{bmatrix} POmel_{t-1} \\ ElasticityD_{t-1} \\ Q_{Cv}OM_{t-1} \end{bmatrix}$$

From the standard deviations associated with the vector $\beta$, in which $\alpha POmel = \alpha Qc_v OM = 0$, and the statistical result, it is possible to reject the null hypothesis that the OMEL Price, and $Q_{Cv}OM$ are weakly exogenous to the cointegration vector. Through this restriction, it is possible to rewrite the ECM equation as: $ECM = Elasticity + 0.00256 POmel - 0.000235 Q_{Cv}OM$ .

The Chi-Square statistic value of 4.472 imposes the rejection of the null hypothesis, proving that $POmel$ and $Q_{Cv}OM$ had some long-term influence on the evolution of the demand price elasticity. Therefore, according to statistical evidence that shows that when there is an imbalance in the estimated long-term relationship (when equality does not occur), $POmel$ and $Q_{Cv}OM$ move themselves towards a state of recovered equilibrium. Through this, it seems that the VECM do not present auto-correlation problems or residual non-normalities. This is presented in Table 3, according to F and Chi-Square tests.

**Table 3. Auto-correlation and normality Test**

| *Tests* | *Statistics* |
|---|---|
| Normality test: $Chi^2(2)$ | 313.13** |
| Hetero test: F(130,1242) | 6.51** |
| Reset test: F(1,1372) | 447.47** |

** significant at 1%.

In light of these results, and at a 1% level of significance, the auto-correlation hypothesis is rejected. This shows that the specification does not present problems, in other words, the results for these statistics, reject the null hypothesis of absence of residual auto-correlations.

It is possible to express the cointegration vector as a function of any one of the variables, regardless of the causal direction.

*4.2.2. Cointegration between OMEL price ( $POmel$ ), and quantity purchased for sale in open market ( $Q_{Cv}OM$ ) under the absence of regulation*

The results of the trace test, shown in Table 4, point towards the existence of merely one cointegration vector.

**Table 4. Cointegration – Johansen Trace Test**

| *H0* | *H1* | *Trace test [prob]* | | *Max test [prob]* | |
|---|---|---|---|---|---|
| *r*=0 | r>0 | 34.5 | ** | 33.45 | ** |
| *r*=1 | r>1 | 3.4 | | 3.3 | |

** significant at 1%.

The results for OMEL price and $Q_{Cv}OM$ with market data reveal that the quantity purchased in the spot market series shows a break in the structure in January 2004. Accordingly, we decided to include a restricted dummy in the cointegration vector. Tests indicate that cointegration exists and that uniequational representation is not possible. This appears to be a consistent result: price and quantities mutually influence each other.

**Model output 2**

Estimated cointegration vector (VECM) between OMEL price and quantities purchased in spot for sale in open market

$$\begin{bmatrix} POmel \\ Q_{Cv}OM \end{bmatrix} = \begin{bmatrix} -0.0410 \\ -0.0560 \end{bmatrix} \begin{bmatrix} 1 & 1.1068 & -4.8389 \end{bmatrix} \begin{bmatrix} POmel_{t-1} \\ Q_{Cv}OM_{t-1} \\ Shift2004_{t-1} \end{bmatrix}$$

After imposing the restriction, and based on the standard deviations associated with the vector *β*, it is possible to conclude that this coefficient may be different from zero.

The estimated long-term relationship can be expressed as follows:

$$ECM = POmel - 1.1068 Q_{Cv}OM + 4.8389 Shift_{2004}$$

A Chi-Square value of 13.316 imposes the rejection of the null hypothesis, and reflects the fact that the variable $Q_{Cv}OM$ had some long-term influence on the evolution of the real price, i.e., the quantities purchased for sale in open market influence the real price in such a way that, when there is an imbalance in the estimated long-term relationship, real prices move towards a state of recovered equilibrium.

In light of the analysed results, we can express the cointegration vector as a function of any one of the variables, regardless of the causal direction. Therefore, the existence of cointegration between the OMEL price and the quantity purchased in the spot market for sale in open market is proven. This confirms the proposition that in profit maximisation decisions of electricity companies that operate in the spot market, it is important to include this variable in bidding decisions.

The residuals do not present signs of auto-correlation. However, tests do not conclude that they have normal distribution. If in the OMEL price equation the situation is not overly concerning, in the quantities purchased for sale in open market equation, the tails are clearly more substantial when compared to a normal distribution.

*4.2.3 Cointegration between price cap ($\Pr Cap$) and quantity purchased for sale in open market ($Q_{Cv}OM$) under the presence of regulation*

The results of the trace test, shown in Table 5, point towards the existence of only one cointegration vector. Nevertheless, the cointegration evidence involving the price cap is weaker when compared to the case of the OMEL price.

**Table 5. Trace Test**

| *H0* | *H1* | *Trace test [prob]* | | *Max test [prob]* | |
|---|---|---|---|---|---|
| *r*=0 | r>0 | 37.58 | ** | 33.75 | ** |
| *r*=1 | r>1 | 3.82 | | 3.83 | |

** significant at 1%.

**Model output 3**

Estimated Cointegration Vector (VECM) between Price Cap and Quantities Purchased for Sale in Open Market

$$\begin{bmatrix} \Pr Cap \\ Q_{Cv}OM \end{bmatrix} = \begin{bmatrix} -0.0494 \\ -0.0942 \end{bmatrix} \begin{bmatrix} 1 & 0.6590 & -2.9040 \end{bmatrix} \begin{bmatrix} \Pr Cap_{t-1} \\ Q_{Cv}OM_{t-1} \\ Shift2004_{t-1} \end{bmatrix}$$

After imposing the restriction, and based on the standard deviations associated with the vector *β*, it is possible to conclude that the vector *β* is different from zero.

As in the model presented in the previous section and based on the OMEL price, it is not possible to find evidence that none of the variables are exogenous with respect to the cointegration vector. Therefore, the VECM-VAR representation would be more correct, indicating that prices and quantities purchased for sale in open market influence each other. The estimated long-term relationship was:

$$ECM = \Pr Cap - 0.659 Q_{Cv}OM + 2.904 Shift_{2004}$$

This equation reflects the market power mitigation effect of the regulatory mechanism. An increase of 1 KWh of electricity purchased on the spot market for sale in the retail market induces an average price increase of 0.659, thus reducing the exercise of market power. In real terms, considering the effect of the CTCs mechanism, this result also shows the importance of the variable quantity purchased for sale in the open market, i.e. the position of net demander or net supplier influences the actual market power exercise. Thus, it is a strategic variable with significant impact on the profit function of the electricity companies, as supported by Kühn and Machado (2004).

A Chi-Square value of 13.447 confirms the rejection of the null hypothesis, and indicates that the quantities purchased for sale in open market influence the price cap in such a way that when there is an imbalance in the estimated long-term relationship the price cap moves to recover a state of equilibrium.

*4.3. The study of long-run and short-run causality among the three major Spanish electricity firms: Endesa, Iberdrola, and Unión Fenosa*

For Unión Fenosa, it was possible to estimate a cointegration vector with real price weakly exogenous to the cointegration vector, however, there was a need to introduce a dummy variable in order to correct for the effect of rising quantities purchased for sale on the open market in June of 2007.

As it was not possible to estimate cointegration models for Endesa and Iberdrola, we adopted a new methodology: we differentiated the OMEL price and estimated a classic regression model including gaps between explained and explanatory variables, in order to eliminate evidence of auto-correlation. In this situation, what is being modelled is the variation of price according to marginal costs ( $MCost$ ), quantity sold in the OMEL spot market ( $Q_v$ ), quantity purchased in the spot market to sell in open market ( $Q_{Cv}OM$ ), the conduct parameter associated with quantity sold in the spot market ( $\theta Q_v$ ) and the conduct parameter associated with the quantity purchased in the spot market and sold in the open market ( $\theta Q_{Cv}OM$ ), all of which for the three electricity companies.

***4.3.1. New long-run estimated causality for individual companies***

After the preliminary analysis to find breaks in the time series structures of Endesa, we found significant breaks in the conduct parameters $\theta Qv$, and $\theta Q_{Cv}OM$ , and Endesa's $Q_{Cv}OM$ . In the models presented, only the statistically significant variables remain, with the dummy variables always being excluded. It should be noted that although $\theta Qv$, and $\theta Q_{Cv}OM$ gaps were retained in their respective models: (a) no unlagged conduct parameter was significant, and (b) $\theta Q_v$ and $\theta Q_{Cv}OM$ lags could have been removed without significant impact to the level of auto-correlation, and the model's explanatory power.

For the abovementioned reasons, we obtained, for Endesa and Iberdrola, respectively, the following steady-state equations, determined by the estimated coefficients.

**Endesa**

$$\Delta POmel_{t-1} = -\ 0.05803\ +\ 0.0151\Delta MCost_{t-1\,Endesa} -\ 0.02501\Delta\theta Qv_{t-1\,Endesa}$$

$$\Delta POmel_{t-1} = -0.031224\ +\ 0.01558\Delta MCost_{t-1Endesa} +\ 0.0042216\Delta\theta Q_{Cv_{t-1}Endesa}$$

These two long-term relationships estimated for Endesa reveal that for the regular levels of significance, Marginal Costs ( $MCost$ ), and the conduct parameters $\theta Q_v$ and $\theta Q_{Cv}OM$ are the variables that influence the first differences of OMEL prices.

The estimated coefficient for conduct parameter $\theta Q_v$, in the long-term relationship, is 0.025€/MWh. A deviation in the long-term equilibrium of the conduct parameter $\theta Q_{Cv}OM$ negatively influences the OMEL price (first difference). Equally, a deviation in the long-term equilibrium of the conduct parameter positively influences (by a factor of 0.0042€/MWh) the OMEL price.

**Iberdrola**

$$\Delta POmel_{t-1} = 0.07616\ -\ 0.324288\Delta MCost_{t-1\,Iberdrola} -\ 0.17335\Delta Qv_{t-1Iberdrola} -\ 0.0720306\Delta\theta Qv_{t-1Iberdrola}$$

$$\Delta POmel_{t-1} = 0.053203\ -\ 0.3373\Delta MCost_{t-1Iberdrola} -\ 0.0769\Delta Qc_{vt-1Iberdrola} -\ 0.07242\Delta\theta Qc_{vt-1Iberdrola}$$

For Iberdrola, at the 5% significance level, the variations (the first differences) of marginal costs ( $MCost$ ), quantities purchased in the spot market for sale in open market and the conduct parameters $\theta Q_v$ and $\theta Q_{Cv}OM$ influence the first differences of the OMEL price. The estimated coefficient for conduct parameter $\theta Q_v$, in the long-term relationship is 0.173€/MWh. A deviation in the long-term equilibrium of the conduct parameter $\theta Q_{vIberdrola}$ negatively influences (by a factor of 0.0720€/MWh) the OMEL price (first difference). Equally, a deviation in the long-term equilibrium of the conduct parameter $\theta Q_{CvIberdrola}$ negatively influences the OMEL price (by a factor of 0.0724€/MWh).

These results, for both Endesa and Iberdrola, confirm the hypothesis that the conduct parameter $\theta Q_{Cv}OM$ has the inverse behaviour of the conduct parameter $\theta Q_v$ when the explained variable reveals causality with the exercise of market power.

**Unión Fenosa**

$$\Delta Qv_{t-1_{UFenosa}} = 0.2302 + 0.2192\Delta POmel_{t-1} + 0.1689\Delta\theta Qv_{t-1UFenosa} - 1.537\ \text{Shift}\Delta Qv_{t-1UFenosa}$$

$$\Delta Qc_{vt-1}OM_{UFenosa} = 0.027 + 0.2306\Delta POmel_{t-1} + 0.0282\Delta\theta Qc_{vt-1}OM_{UFenosa} - 1.607\ \text{Shift}\Delta Qc_{vt-1}OM_{UFenosa}$$

The estimated coefficients for the conduct parameters $\theta Q_v$ and $\theta Q_{Cv}OM$, in the long-term relationship are 0.169 and 0.028€/ MWh respectively. Both are interpreted as a convergence rate for long-term equilibrium. This means that an increase of $\theta Q_v$ ($\theta Q_{Cv}OM$), in a certain year, includes the correction of approximately 0.169 (0.028) for the previous year's long-term relationship imbalance.

A summary of the tests run for all equations for Endesa, Iberdrola and Unión Fenosa is shown in Table 6. The F-statistic aims to test if the coefficients associated with the explained variables are, as a whole, significantly different from zero. In other words, it tests if ECM is statistically significant and if, as a consequence, we can admit that cointegration exists.

**Table 6.** Summary of Test Results/Statistics

| | *Endesa* | | *Iberdrola* | | *Unión Fenosa* | |
|---|---|---|---|---|---|---|
| Wald Test $\chi^2(3)$ | 11.716** | 9.3315** | 110.76** | 100.03 | 34.014** | 35.626** |
| AR 1-2 (F Test) | 0.88722 | 1.6251 | 1.0491 | 0.08433 | 0.69332 | 0.39121 |
| ARCH -1-1 (F Test) | 53.44** | 53.25** | 27.890** | 34.598** | 46.699** | 43.257** |
| Normality Test $\chi^2(1.2)$ | 162.88** | 190.27** | 125.68** | 116.46** | 215.19** | 237.96** |
| Hetero Test (F Test) | 3.7578** | 4.1770** | 2.8539** | 3.0999** | 3.0274** | 2.9793** |
| Reset Test (F Test) | 7.8811** | 12.609** | 9.5549** | 11.837** | 5.1219* | 7.528** |

** significant at 1%;
* significant at 5%.

The models used are characterised, among other aspects, by the absence of auto-correlation and approximations of normal distribution. Evidence indicates that the estimated ECMs, at the 1% significance level, do not present auto-correlation problems or residual non-normalities. The Reset tests and the exclusion of dummy variables indicate that the specifications do not present problems. In other words, the results for these statistics, at a 1%significance level, imply the rejection of the null hypothesis for the absence of residual auto-correlation in all models used.

#### *4.3.2. Generalised impulse response function*

An impulse response analysis can be used to study the effects of shocks on system variables. An Impulse Response Function (IRF) shows how a positive and unexpected shock that directly affects one variable can influence another variable throughout time.

Figures 1.1a, 1.2a, and 1.3a firstly present impulse response functions showing the changes in the quantity sold in the spot market ($Q_v$), and the quantity purchased in the spot market to sell in open market ($Q_{Cv}OM$) resulting from one shock in market price ($POmel$), for the major companies in the market, Endesa, Iberdrola and Unión Fenosa. Secondly, the changes in market price ($POmel$) to one shock in the quantity sold in spot market ($Q_v$) and to one shock in the quantity purchased in spot market to sell in open market ($Q_{Cv}OM$) are shown in Figures Figure 1.1b, 1.2b, and 1.3b.

After a positive shock in the OMEL market price, the return to the initial quantities sold in the spot market stabilize after approximately eight days and the impact on the quantity purchased in the spot market to sell in open market is almost zero. This indicates that the abovementioned market players have a short position when bidding purchased quantities at time *t* and have a long position when bidding sold quantities.

**Figure 1.1a.** Impulse: Market price; Response: Purchased and Sold Quantity (Endesa)

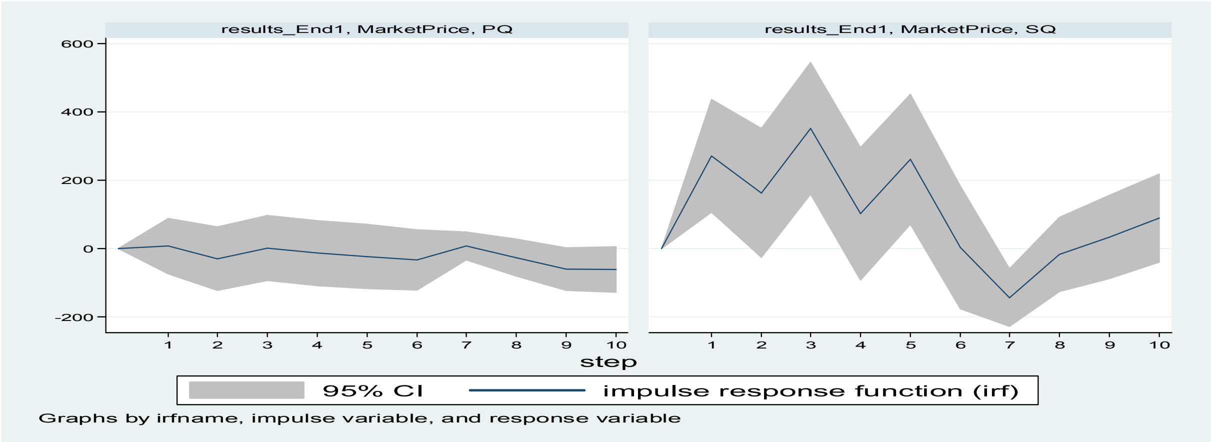



**Figure 1.2a.** Impulse: Market Price; Response: Purchased and Sold Quantity (Iberdrola)

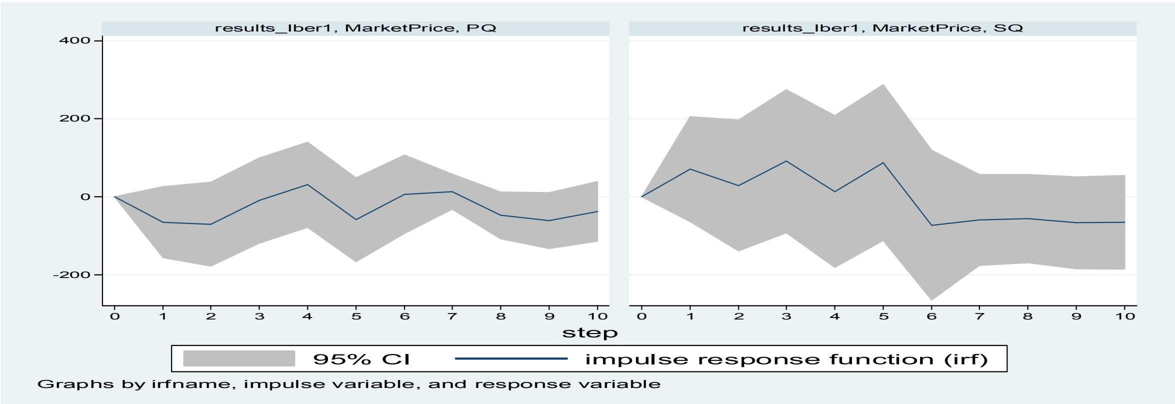
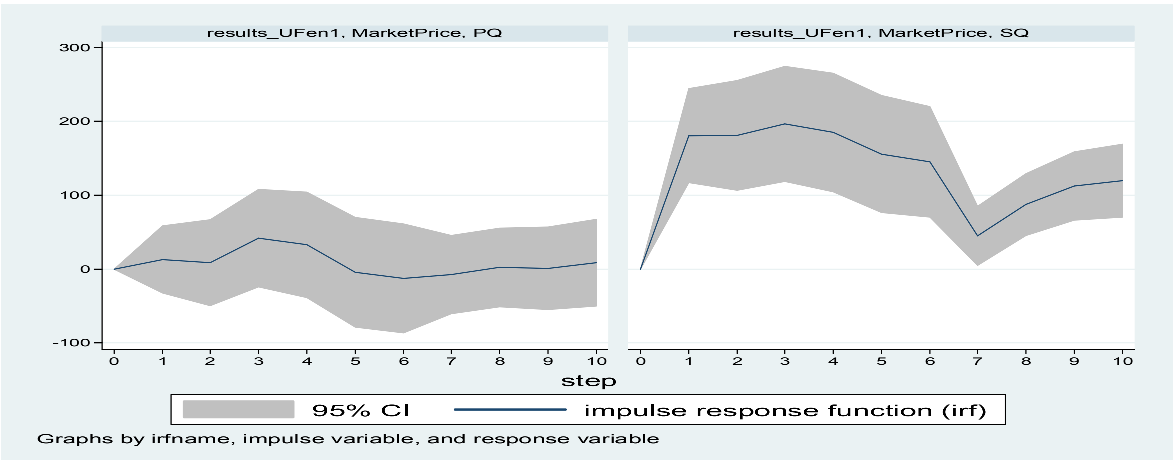



**Figure 1.3a.** Impulse: Market price; Response: Purchased and Sold Quantity (Unión Fenosa)




Figures 1.1a, 1.2a and 1.3a show the IRF of the effect of the OMEL market price on the quantity sold in the spot market (for Endesa, Iberdrola and Unión Fenosa), indicating that a positive shock in market prices causes a significant positive effect on the quantity sold in the spot market, and the effect is persistent over a period of ten days. The most pronounced change in the quantity sold in the spot market as a consequence of the OMEL Market Price can be observed for Endesa. Contrastingly, changes in the quantity purchased in the spot market to sell in open market as a response to a shock in the OMEL market price are almost non-existent and die out quickly after time $t+1$.

**Figure 1.1b.** Impulse: Purchased and Sold Quantity; Response: Market price (Endesa)

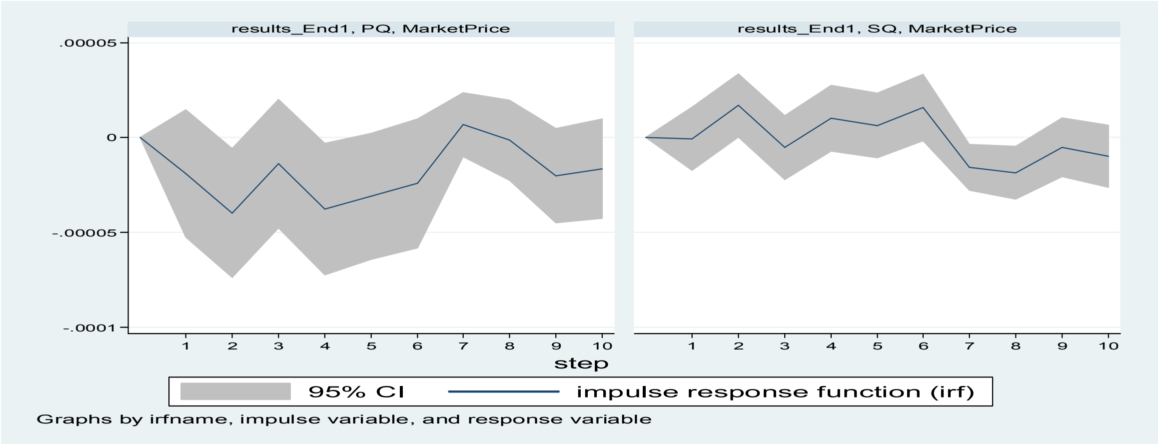



**Figure 1.2b.** Impulse: Purchased and Sold Quantity; Response: Market price (Iberdrola)

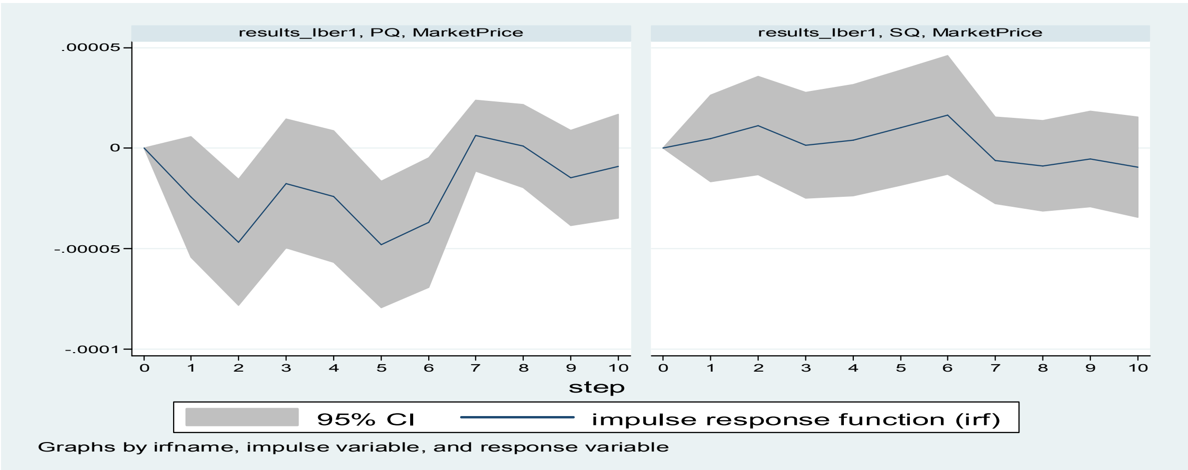
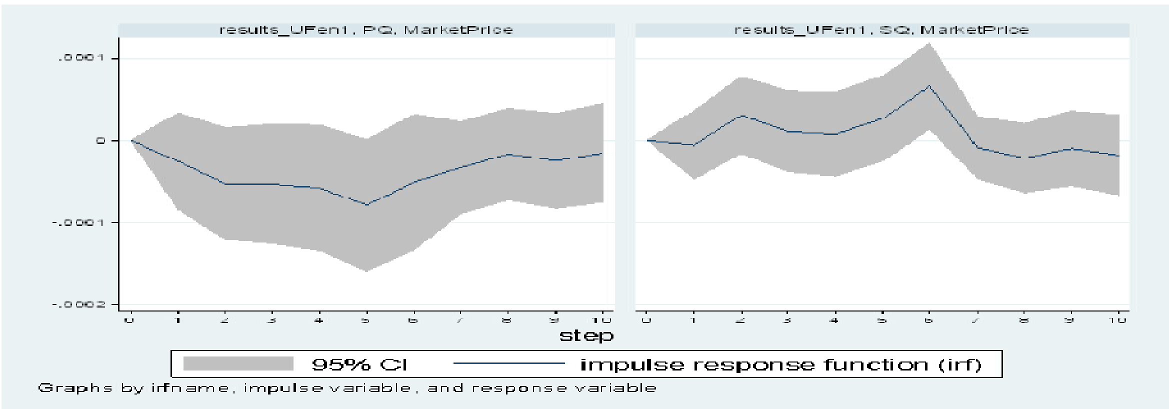



**Figure 1.3b.** Impulse: Purchased and Sold Quantity; Response: Market Price (Unión Fenosa)




The OMEL market price response is negative and significant for Endesa, Iberdrola and Unión Fenosa regarding shocks in the quantity purchased in the spot market to sell in open market ( $Q_{Cv}OM$ ). The return to the initial value for the market price only occurs after seven days. On the other hand, the OMEL market price response to one shock in the quantity sold in the spot market ( $Q_v$ ) is positive and significant, and returns to its initial value after five days for Endesa, Iberdrola and Unión Fenosa. These findings imply that the OMEL electricity market price does respond, in the short-run, to the quantities set (to sell and purchase) in the spot market to sell in open market. Thus, the long and short-run analysis based on the IRFs justifies the long and short-run causality results, which implies that the

OMEL market price does play an important role in stabilizing the short and long-run quantities set in the spot market.

Figures 2.1a, 2.2a, and 2.3a firstly present the impulse response functions for changes in the conduct parameters $\theta Q_v$ and $\theta Q_{Cv}OM$, to one shock in $Q_v$ and $Q_{Cv}OM$ respectively for Endesa, Iberdrola and Unión Fenosa respectively. Secondly, the changes in quantity sold in the spot market ($Q_v$) and in quantity purchased in the spot to sell in open market ($Q_{Cv}OM$) resulting from a shock to the conduct parameters $\theta Q_v$ and $\theta Q_{Cv}OM$ are shown in Figs 2.1b, 2.2b, and 2.3b.

**Figure 2.1a.** Impulse: Purchased and Sold Quantity; Response: $\theta Q_v$ and $\theta Q_{Cv}OM$ (Endesa)

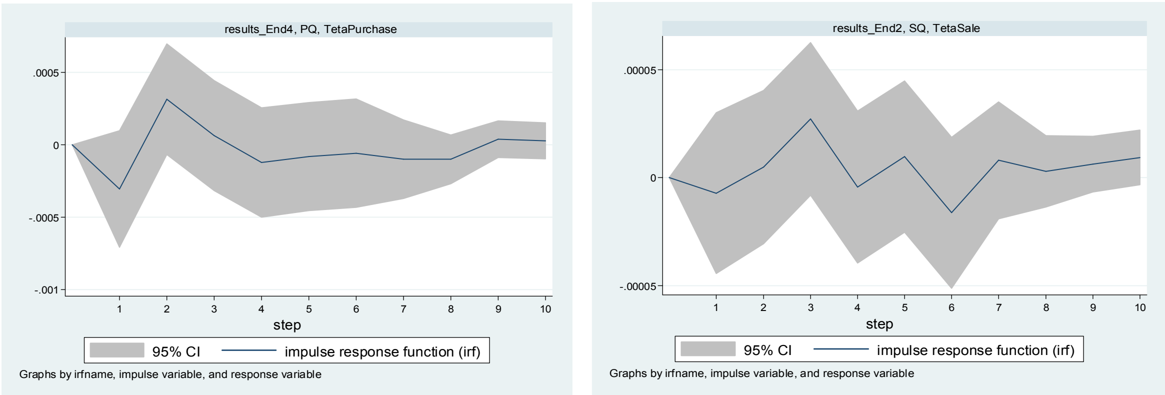



**Figure 2.2a.** Impulse: Purchased and Sold Quantity; Response: $\theta Q_v$ and $\theta Q_{Cv}OM$ (Iberdrola)

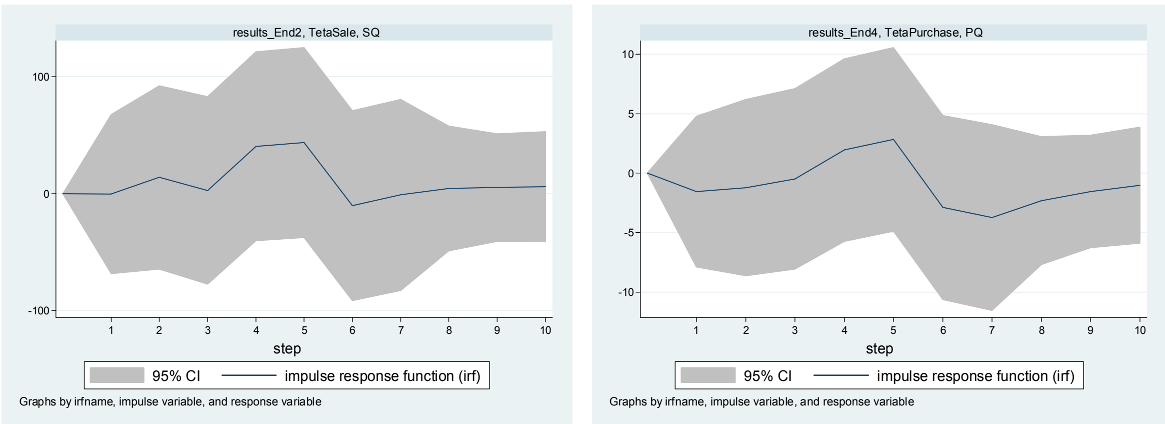



**Figure 2.3a.** Impulse: Purchased and Sold Quantity; Response; $\theta Q_v$ and $\theta Q_{Cv}OM$ ; (Unión Fenosa)

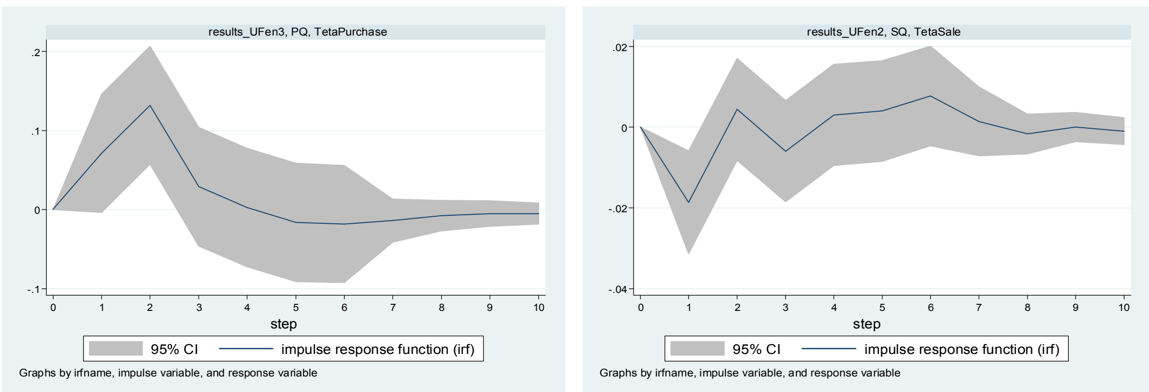


**Figure 2.1b.** Impulse: $\theta Q_v$ and $\theta Q_{Cv}OM$ ; Response: Purchased and Sold Quantity (Endesa)

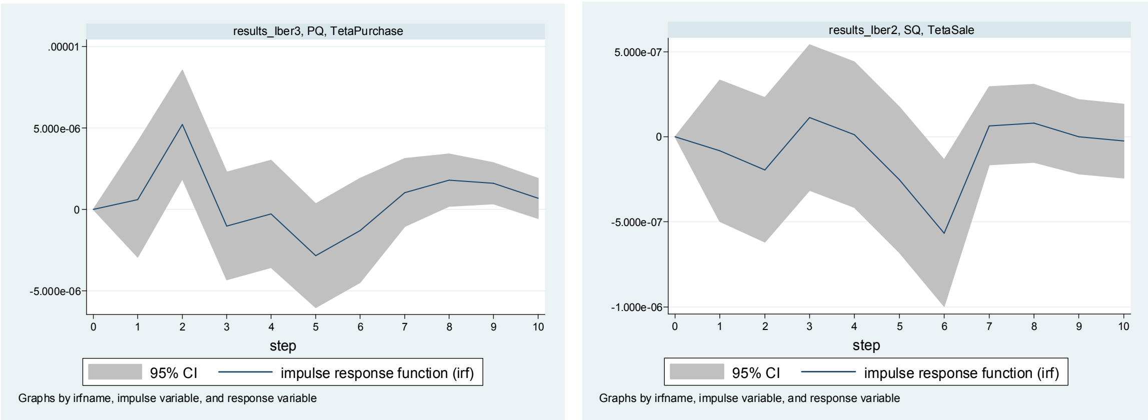



**Figure 2.2b.** Impulse: $\theta Q_v$ and $\theta Q_{Cv}OM$ ; Response: Purchased and Sold Quantity; (Iberdrola)

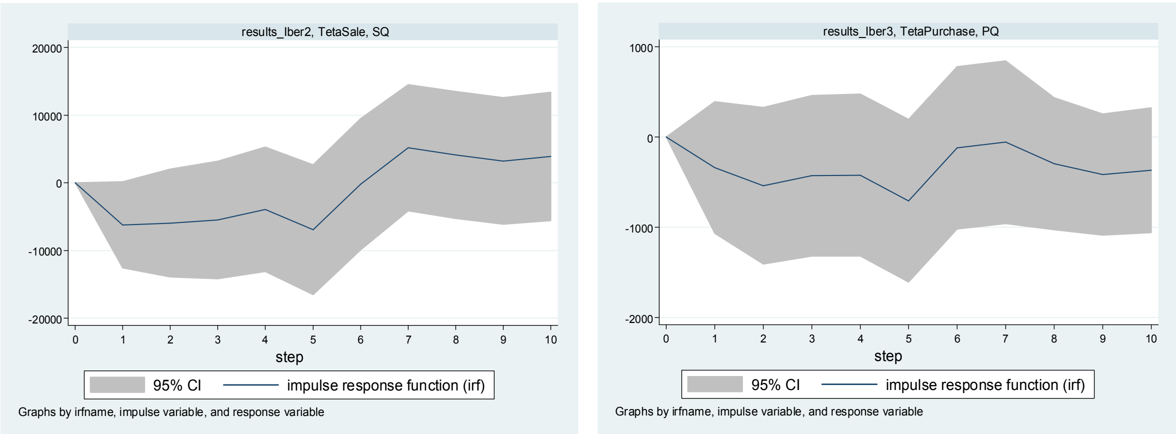
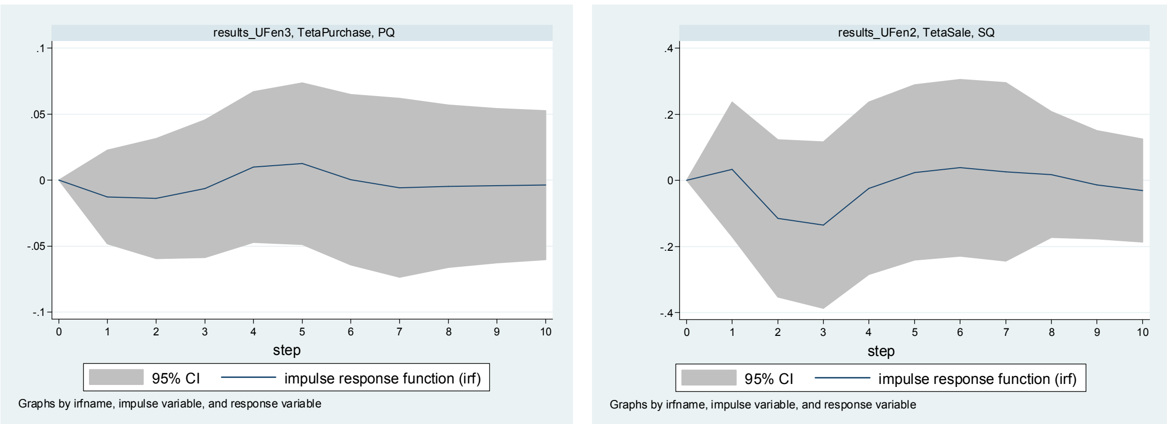



**Figure 2.3b.** Impulse: $\theta Q_v$ and $\theta Q_{Cv}OM$ ; Response: Purchased and Sold Quantity (Unión Fenosa)




Looking at the short-run impacts of the conduct parameter shocks on the quantities set for sale ($Q_v$) and on the quantities purchased in the spot market to sell in the open market ($Q_{Cv}OM$), the results illustrate two points of note arising from the initial impact: (i) sold quantities $Q_v$ decrease for both Iberdrola and Unión Fenosa, and increase in the case of Endesa; (ii) a slight increase in $Q_{Cv}OM$ occurs for Endesa and Unión Fenosa, and a decrease for Iberdrola.

As regards shocks in $Q_v$ and $Q_{Cv}OM$ , a negative initial statistically significant impact on the conduct parameter $\theta Q_v$ is observed for Unión Fenosa and Iberdrola. Endesa, however, reveals a positive reaction to the shock. After 6 or 7 days the shock impacts diminish and show a particular trend thereafter. The shocks in $Q_{Cv}OM$ have an opposite effect on the conduct parameter $\theta Q_{Cv}OM$, *vis-à-vis* what was previously mentioned.

Clearly, conduct parameters $\theta Q_v$ and $\theta Q_{Cv}OM$ do react to anticipated fluctuations in the short-run Cournot behaviour, which is consistent with the long-run causality results.

In summary, it is possible to conclude that shocks in the spot market sale bids will cause significant behavioural changes for Endesa, at $t$+1 and $t$+2 after the shock, where regimes of intermediate competitive intensity with regimes of collusion predominate, for both sale and purchase bids.

On the other hand, for Iberdrola, shocks in the spot market purchase bids cause two alternative responses in the first two days after the shocks: one based on Cournot-like competitive regimes, and the other based on collusive-like regimes. Moreover, shocks in sale bids lead to intermediate intensity competitive regimes, confirming the premise supported in this study that the sale and purchase bids in the spot market would be symmetrical between the two biggest players, Endesa and Iberdrola. Unión Fenosa behaves as a typical follower, acting as if Iberdrola were the market leader.

## 5. Conclusions

This paper analyses the impact of variables with the potential to explain the use of market power in the spot electricity market. Therefore, as a first step, a cointegration study was carried out using aggregated market data. The results reveal that the use of market power presents a stable long-term relationship with quantities purchased for sale in open market. Thus, quantities purchased for sale in open market influence real prices in such a way that when an imbalance occurs in the estimated long-term relationship, OMEL prices move in the direction of the recovered equilibrium. This result reveals that, in light of the individual significance of OMEL prices and the dummy variable in the model, OMEL prices influence the quantities purchased for sale in open market, i.e., for the long-term relationship, OMEL prices are weakly exogenous to the cointegration vector whereas quantities purchased for sale in open market move towards a long-term re-established balance.

In these relationships, and in light of the individual significance of the variables included in the model, we can state that, for the habitual levels of statistical significance, the first difference variations of marginal costs, quantities purchased in the spot market for sale in open market, and the conduct parameters influence the first differences of real prices. In other words, when there is an imbalance in the estimated long-term relationship, the first differences of OMEL Prices adjust in order to reinstate the balance.

The price cap criterion followed by the regulatory authorities determine the weighted average right incentives for mitigating the market power is very important in context of transition to competition in the Spanish wholesale electricity market. Those incentives provided by the regulation may interfere with the day-ahead market and result in lower prices than the ones predicted by the profit maximisation behaviour.

Even though the long-run causality analysis fails to indicate causal linkages between either set quantities of electricity sold and purchased in the spot market for sale in the open market or conduct parameters and electricity spot prices, there may be some short-run temporary effects.

In this respect, additional information was revealed through plots of the generalised impulse response function based on a one-off shock to set quantities sold, quantities purchased in the spot market for sale in open market, and the conduct parameters, with the response being measured though the OMEL spot market price.

In summary, our results point to the efficacy of the CTC payment effect in mitigating the market power exercise in the regulatory period of 2002-2007 of the Spanish electricity market. However, during this period the differences of the quantities purchased in the spot market for sale in open market significantly influence spot prices when considering the mitigation of market power in setting the price cap. Thus, if on the one hand, one should note the success of CTCs, since there was a decrease in the exercise of market power, on the other hand, the maximisation of the profit function is affected by the quantity purchased on the spot market for sale in the retail market, as the purchaser or seller position clearly affects the decisions in the quantities game as admitted in the theoretical model.

Finally, our results suggest that the electricity spot price with firms that exercise differing degrees of market power may show different degrees of competitive behaviour to alter quantities sold in the spot market and quantities purchased in the spot market for sale in open market. A new line of research could focus on the direct and indirect effects of set quantities sold and purchased in the spot market on prices in both the electricity spot and open markets.

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