Empirical relationships between spot, futures and forward prices traded in the Iberian Electricity Market (MIBEL)

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The authors are gratefully acknowledge the financial support of the Spanish Ministry of Education and Science.

JEL classification: G14, C3, Q4

Keywords: Electricity, futures prices, Efficiency.

Abstract:

This paper analyzes the relationships between prices related to Spanish area from different markets within MIBEL (Iberian Electricity Market), namely futures, spot and OTC forward markets. Such an analysis focuses on 3 aspects: (i) market validity by contrasting the weak efficient hypothesis, (ii) efficiency of the futures market in the long term and short-term causality and, finally, (iii) price discovery relationships between the involved series of prices. The empirical results confirm that MIBEL (both spot and futures) prices satisfy the weak efficient hypothesis. Moreover, MIBEL futures market is efficient in the long-term and there is unidirectional short-term causality from the futures price to the proxy of the spot price. Lastly, price discovery relationships are also found. In particular, unidirectional causality from the futures market to the forward market and to the spot market for 1-month- and 1-quarter-ahead maturities.

1 Introduction

The deregulation process in European energy markets is a reality. The Spanish and Portuguese electricity market make up the Iberian Electricity Market (MIBEL), setting up different markets where agents can go. There exist two distinguished areas in MIBEL, the Spanish area and the Portuguese area. Usually wholesale spot prices are the same and only differ due to congestions between both areas, which are managed by a market splitting mechanism Thus, in the spot market the generators and the retailers have a "pool" where they cross their supply and demand of electricity for the next day. Complementary to this market, there exist an intraday market where agents can go to trading few hours before the maturity date. Besides, there exists the system services market for adjusting the balance between production and consumption. Additionally, agents can trade futures contracts through the derivatives exchange (OMIP[1]) and OTC physically- or cash-settled bilateral forward contracts. Each futures contract involves the supply / reception of electricity to a constant power of 1 MW during all hours of the delivery period (according to the maturity of each contract). The maturities that are admitted to trading are weekly, monthly, quarterly and yearly. In the OTC market, agents contract power bilaterally without the presence of a Clearing House. By definition, the OTC market allows for the negotiation of non-standardized contracts that exactly fit the interests of the parties involved in each operation. However, this research focuses on forward contracts that are analogous to futures contracts traded on the regulated futures market. The OTC market provides agents with an alternative to the regulated futures market to hedge the risk of price variation. In this sense, it should be noted that the Spanish OTC market is prior to the futures market, existing transaction records from Reuters database since February 2003[2].

As a consequence of market liberalization, a relevant risk associated to the electricity markets is the price variation risk, due to the high volatility of the spot

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[1] Iberian forward market operator.

[2] The volume traded in 2010 in the futures market was 25 785.4 GWh, while the OTC market volume reached 474.4 275 GWh (CNE, 2011).

price. Furthermore extreme values usually appear more often than in other commodities markets[3]. This characteristic could turn into a critical situation for the electrical companies that do not hedge this risk. In this sense, futures market as well as OTC forward markets help manage this price variation risk, although the latter has an added risk, the counterparty risk.

In this context, it is crucial to know the relationships between the different market prices within MIBEL so as to participants can take optimal decisions. The CNE[4] explicitly encourages the monitoring of Spanish OTC forward market and its relationships with the rest of forward markets such as OMIP (CNE, 2010). According to the CNE, forward prices influence prices resulting from the CESUR auctions[5], and the calculation of the last resort tariff (TUR), which nowadays affects more than 23 million of consumers, is estimated based on prices from CESUR auctions.

It is worth mentioning that the analysis of the relationships between spot and futures prices has been the subject of many theoretical and empirical studies. In the literature it is well known that the *cost-of-carry* relationship allows the prices of both the forward and spot markets to be linked (assuming the hypothesis of absence of arbitrage opportunities). However, the no-arbitrage condition involves taking position in both markets and storing the underlying asset until the expiration date of the futures contract. Given that electricity is not susceptible to storage, the *cost-of-carry* model as a theoretical framework for relating the spot and forward prices is not applicable in this context. In fact, the determinants of the so-called spot (day-ahead) price for electricity are different from those of the price for electricity for the week, month, quarter or year ahead (forward price) and, in this sense, each of these price series refers to distinct underlying assets[6].

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[3] For more details about the characteristics of electricity prices see Bessembinder and Lemmon (2002).

[4] Spanish National Energy Commission.

[5] CESUR auctions are created for the purpose of determining the estimated cost of wholesale contracts in order to calculate the last resort tariff.

[6] In order to use the *cost-of-carry* relationship to link spot and futures price in Nord Pool, Deng (2005) argues the possibility of storing electrical energy indirectly, through the water stored in reservoirs, and then used to generate electricity.

Despite this, some articles have tested the efficiency of electricity markets by analyzing the relationships between spot and forward prices without taking into account these considerations (Deng, 2005; Feng *et al.*, 2007 and Yang *et al.*, 2009, among others). The purposes of these analyses were the empirical testing of causality between prices for both markets. However, these studies do not have theoretical arguments whereby both series of prices should be related, but, according to our view, are limited to analyzing potential causal relationships between two markets with different underlying asset. Consequently, their results may not have implications for a higher or lower degree of market efficiency.

So, to address the issue of the efficiency of the MIBEL futures market, this research focuses on the relationships between futures prices and an approximation of spot prices derived from the seasonal *cost- of-carry* model proposed by Borovkova and Geman (2008), which is aimed to capture the dynamics of the electricity prices better than the classical *cost-of-carry* model.

In the literature, the analysis of the relationships between electricity forward and spot prices has been addressed through different approaches. Thus, Bessembinder and Lemmon (2002) propose an equilibrium model, where the prices are determined by the market participants and firms only focus on the mean and the variance of their profits to make their decisions. These authors conclude that there exists a negative (positive) relationship between the forward risk premium (defined as the difference between the forward and the spot price) and the variance (standardized skewness) of the spot price. Also, they obtain empirical verification of their model using monthly forward contracts of the American markets PJM[7] and CALPX[8] for the 1997-2000 period. Subsequently, a wide set of studies directly analyzes the presence of forward premium. Shawky et al. (2003) focuses on the weekly futures contracts of COB[9] for the period 1998-1999, concluding that electricity markets have more forward premium and hedge ratio than other non-electrical commodities markets. Longstaff and Wang (2004) use hourly spot and day-ahead electricity prices from the PJM market for the period

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[7] Pennsylvania, New Jersey, Maryland.

[8] California Power Exchange.

[9] California and Oregon frontier.

2000-2002, finding the existence of a varying positive forward premium throughout the day and directly related to economic risk factors, like the volatility of unexpected changes in demand, spot price and total revenues. These results confirm the empirical evidence of Bessembinder and Lemmon's model (2002) for the analyzed period. Worthington and Higgs (2004) conclude that there is a linear causality from futures prices to spot prices in the Australian electricity markets of New South Wales and Victoria. Besides there exist a greater degree of efficiency in the off-peak markets than the peak markets concerning the transfer of information from futures to spot prices.

In the context of the European electricity markets, several works have focused on the Scandinavian market (Nord Pool). Among them, Boterrud *et al.* (2002) analyze the ex-post premium of the weekly future in the period 1995-2001, obtaining that futures prices on average excess spot prices, and there exists a negative premium in the futures market due to the difference in flexibility on the supply and demand side. Afterwards, Boterrud *et al.* (2010) extend the analyzed sample to 2006 and conclude that also the futures prices tend to be higher than spot prices and the relationship between spot and futures prices is linked to the hydro inflow, reservoir levels and demand. Lucia and Torró (2011) investigate the ex-post premium as well as the basis of the weekly contracts for the period 1998-2007, concluding that a significant positive premium on average exists, and it varies throughout the year, being positive in winter, autumn and spring and zero in summer. In addition, these authors obtain evidence in favor of the Bessembinder and Lemmon model (2002)'s implications until 2003. On the other hand, Viehmann (2011) examines the hourly prices of the daily futures contract in the German market (EEX[10]) for the period 2005-2008, finding positive premiums in the weekday afternoons of winter and negative premiums for the lowest energy demand hours. Also, Viehmann (2011) founds that risk premiums are positive related to the tightness factor that measures the illiquid moments of the market.

As regards MIBEL, on the one hand, Capitán and Rodríguez (2009) use the monthly and quarterly futures contracts from 2006 to 2008 to estimate the ex-post

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[10] European Energy Exchange.

premium. According to their results, these two contracts have similar behavior and positive premium in the analyzed period. On the other hand, Furió and Meneu (2010), use 1-month ahead forward prices to compute ex-post and ex-ante premiums and conclude that the risk premium depends on unexpected demand variations and on the levels of hydroelectric energy capacity. These authors additionally check the Bessembinder and Lemmon's model (2002) implications in the period 2003-2008, obtaining that they are partially supported by the data.

Finally, as said before, the electricity market efficiency is claimed to be tested by analyzing relationships between spot and forward prices in Yang *et al.* (2009) and Feng *et al.* (2007). Both studies focused on the Scandinavian market, Nord Pool. Thus, Yang et al. (2009) analyze the relationships between spot and weekly futures prices for the period 1996-2003, and conclude that the Nord Pool futures market satisfies the weak efficient hypothesis, and that the futures market plays a dominant role in the price discovery function. Feng *et al.* (2007) analyze the long-term equilibrium relationships between spot and futures market with annual maturity covering the period from January 2005 to June 2006. They obtain unidirectional Granger causality from the futures market to the spot market, being more noticeable in the long term. These authors conclude that Nord Pool futures market confirms the weak efficient hypothesis.

Although the main objective of this study is the analysis of the efficiency of the MIBEL futures market, once it is available a sample period of approximately five years of data since its beginning in July 2006, the efficiency in the short and long term of both, the spot and the OTC forward markets is also studied. Lastly, the interrelationships between the prices of these markets, in order to determine whether there is transmission of information between them, are additionally analyzed.

The paper is organized as follows. Section 2 describes the data used, including a descriptive analysis of them. Section 3 explains the methodology used. Section 4 discusses the results and finally, Section 5 concludes by summarizing the major conclusions reached.

2 Data

Daily MIBEL spot, futures and forward electricity prices are used in this paper[11] , covering from the period July 3, 2006 to April 13, 2011[12]. The considered spot price is the SPEL index published by OMIP, which is obtained as the arithmetic average of the day-ahead market price for the 24 hours of the day. As for the futures and forward prices, 1-week-, 1-month-, 1-quarter- and 1-year ahead maturities are selected. All the prices of the data (spot, futures and OTC prices) used in this work are related to Spanish area.

The last trading day is different for each type of contract. So for 1-week-ahead and 1-month-ahead contracts, the last trading day corresponds to the trading day preceding the day before the eve of the first delivery day. For 1-quarter-ahead contracts, the last trading day corresponds to the second trading day preceding the day before the eve of the first delivery day, and for 1-year-ahead contracts, the last trading day corresponds to the third trading day preceding the day before the eve of the first delivery day. As for this study, for days without trading in the futures market or holidays, prices of the day before are used.

A first approximation of the behavior of the data used can be seen in Table 1, which shows the main descriptive statistics. It can be observed that forward and futures prices are less volatile than spot prices. In addition, we can see that the average of the futures price increases with the delivery period, while the volatility is reduced. This price increase could be interpreted as a payment for a risk premium, which is increasing with maturity, consistently with Botterud et al. (2002) and Longstaff and Wang (2004). From this point on, we use the logarithm of spot, futures and OTC prices.

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[11] The spot and futures prices are extracted from the OMIP database, while forward prices are obtained from Reuters database.

[12] This sample period is used because futures contracts starts trading on July 3, 2006.

Table 1: Descriptive statistics of price series.

FUT_i: future contract price expiring i.

FWD_i: forward contract price expiring i.

SPOT: SPEL index price.

Where i = W +1 (week ahead), M +1 (month ahead), Q +1 (quarter ahead) and Y +1 (year ahead).

	FUT_W+1	FUT_M+1	FUT_Q+1	FUT_Y+1	FWD_W+1	FWD_M+1	FWD_Q+1	FWD_Y+1	SPOT
Mean	45,74	47,70	49,06	50,69	45,52	47,71	47,14	50,44	45,26
Median	42,75	45,47	46,00	50,00	42,75	45,75	45,40	49,57	42,33
Maximum	75,00	74,50	75,08	75,10	85,00	76,25	74,80	75,10	82,13
Minimum	21,90	25,50	29,13	38,33	18,25	25,45	19,90	37,75	3,13
Std. Dev.	12,16	11,52	10,56	7,90	12,51	11,36	12,10	7,96	13,37
Skewness	0,72	0,63	0,57	0,85	0,69	0,61	0,31	0,91	0,48
Kurtosis	2,65	2,42	2,41	3,45	2,72	2,49	2,46	3,49	3,01

3 Methodology

The methodology used in the paper is unit root test, cointegration analysis, error correction models and the market efficiency measure proposed by Kellard *et al.* (1999).

3.1 Unit root test

It is well known that the financial series typically present non-stationary problems. Granger and Newbold (1974) note that if a series has stationary problems, sometimes it can lead us to wrongly conclude that exists a causal relationship between two variables, when really that relationship is only caused by random.

In our paper we use the KPSS test to check the unit roots of the series. Kwiatkowski et al. (1992) propose the KPSS test, in which the null hypothesis is stationarity while the alternative hypothesis is not stationarity.

The KPSS statistic is based on the residuals of the OLS regression of y_t on the exogenous variables x_t:

$$y_t = x_t^{'}\delta + u_t$$

The statistical Lagrange Multiplier (LM) is defined as:

$LM = \frac{\sum_t S(t)^2}{T^2 f_0}$, where f_0, is an estimator of the residual spectrum at frequency zero, S(t) is a cumulative residual function: $S(t) = \sum_{\tau=1}^{t} \hat{u}_\tau$ based on the residuals of the previous regresion and T is the total number of observations. The null hypothesis to be tested is that the error term has zero variance regression.

3.2 Cointegration relationships

Economic theory suggests the existence of equilibrium relationships in the long term between forward and spot prices with the same underlying asset. Although they can fluctuate individually out of equilibrium for some time, there are forces that act to restore that balance.[13]

If there is a stable long-term relationship, the residuals of the regression that explain the relationship between two or more time series must be stationary, even though none of the variables of the model is independently stationary. So if there is a long-term relationship between two or more non-stationary variables, deviations from the long term will be stationary and therefore the variables will be cointegrated.

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[13] In the cointegration equilibrium relationship literature is understood as the relationship that two series maintained throughout the period, but it is possible that a sub-period the variables have diverged.

Johansen and Juselius (1990) propose a procedure based on the principle of likelihood ratio under the assumption of normality, to test for cointegration. This procedure uses the vector error correction model (VECM) that does not distinguish, a priori, any order of causality between variables.

The starting point is the methodology of vector autoregressive (VAR) from the following expression:

$$x_t = A_1 \cdot x_{t-1} + \varepsilon_t$$

Where x_t y ε_t are vectors n×1; A_1 is the parameters matrix (n×n). Subtracting x_{t-1} in both parts of the equation it is obtained:

$$\begin{aligned} \Delta x_t &= A_1 \cdot x_{t-1} - x_{t-1} + \varepsilon_t \\ &= (A_1 - I) \cdot x_{t-1} + \varepsilon_t \\ &= \pi \cdot x_{t-1} + \varepsilon_t \end{aligned}$$

where I is the identity matrix (n×n) and π is (A_1-I). The range of π indicates the number of independent cointegration vectors, which can be obtained by checking the significance of the characteristic root (eigenvalues) of π (λ_i) that establishes the matrix rank. There are several ways to generalize the model: for example, the inclusion of a drift in the equation, the inclusion of a constant in the cointegrating vector, or both at once.

If the time series that makes up x_t are not cointegrated, the range of π is zero and all its characteristic roots are equal to 1. The Johansen cointegration test for determining the number of characteristic roots that are different from the unit can be determined using the two following statistics:

The trace statistic tests the null hypothesis that the number of cointegrating vectors is less than or equal to r against the alternative hypothesis that is not the case:

$$\lambda_{trace}(r) = -T \cdot \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i)$$

Where $\hat{\lambda}_i$ are the estimate values of the characteristic roots obtaining by estimating π and T the total number of observations.

The second statistic (λ maximum) tests the null hypothesis that the number of cointegrating vectors is r against the alternative that is r +1:

$$\lambda_{max}(r, r+1) = -T \cdot \ln(1 - \hat{\lambda}_{r+1})$$

The critical values are obtained by Johansen (1988), although Osterwald-Lenum (1992) recalculated these values through Monte Carlo process, because Johansen (1988) tabulated critical values for a range for a 2 and 5 series, while Osterwald-Lenum (1992) generalizes, extending the number of series to consider. These changed values will be used as critical values in this work.

3.3 Short and long term causality relationships

The VECM is a VAR model that is designed for being used with non-stationary series that we know they are correlated. The VECM restricts the long-term behavior of the endogenous variables to converge to the cointegration relationship, while allowing short-term dynamic adjustment. Moreover, Granger (1983) shows that if the series are cointegrated the VECM model improves the VAR model in efficiency and forecasting.

Thus, the VECM representation illustrates the relationship between the concepts of cointegration and Granger causality, being able to analyze the causality between the series, through the elements of the VECM. Thus, this paper uses an error correction model to test the causality in the short and long term of I(1) and cointegrated time series:

$$\Delta Y_t = \alpha_1 + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \sum_{j=1}^{p} \delta_j \Delta X_{t-j} + \beta_1 \mu_{t-1} + \varepsilon_{t1}$$

$$\Delta X_t = \alpha_2 + \sum_{i=1}^{p} \gamma_i^{'} \Delta Y_{t-i} + \sum_{j=1}^{p} \delta_j^{'} \Delta X_{t-j} + \beta_2 \mu_{t-1} + \varepsilon_{t2}$$

Where β_1 and β_2 coefficients measure the speed of endogenous variable adjustment towards equilibrium. μ_{t-1} is the residual of cointegration regression delayed one period. If the error correction term is significant in both equations ($\beta_1 \neq 0$ and $\beta_2 \neq 0$), there is long-term causality in both directions, so that none of the variables can be considered weakly exogenous with respect to the parameters of the other equation, although, according to Engle et al (1983) the condition that there is no Granger causality is necessary but not sufficient for weak exogeneity. If null hypothesis is accepted ($\delta_j=0$ for j=1,…,p) then we can say that X does not cause Y in the short-term. If it is accepted that $\gamma'_i=0$ for i=1,…,p then we can say that Y does not cause X in short-term. The joint hypothesis testing is done through the Wald test using F statistics and/or χ^2, the number of lags are determined using the Akaike information criterion.

3.4 Market efficiency measure

The analysis of short-term efficiency can be studied by the Granger causality test. Thus, if there is no short-term causality between the futures market and spot market, we can say that there is efficiency in the weak sense in the short term. This measure, however, does not allow quantify the degree of efficiency achieved by the market. Kellard *et al.* (1999) propose an alternative measure of market efficiency that allows for comparisons.

Starting from a quasi-ECM model (VECM where we take only one equation individually) the Kellard's market efficiency measure compares the level of efficiency between different markets.

Quasi-ECM model can be defined as follows:

$$s_t - s_{t-1} = \theta_0 + \theta_1 (f_{t-\tau} - s_{t-\tau}) + \sum_{i=1}^{k} \lambda_i \left(s_{t-i} - s_{(t-\tau)-i} \right) + \sum_{i=1}^{k} \gamma_i \left(f_{t-i} - f_{(t-\tau)-i} \right) + \epsilon_t$$

Where s_t is the spot price, f_t is the price of future, k the number of lags of the yields of endogenous and exogenous variable, and θ_1 measures the speed of endogenous variable adjustment towards equilibrium. The prediction error variance is the variance of ε_t, for which there exists an unbiased estimator of the fitted regression. On the other hand, the market efficiency of the futures market implies an estimate of $f_{t-\tau} + E\left[\left(s_t - f_{t-\tau}\right)\right]$, allowing for the possibility of a systematic risk premium in futures prices and the error variance of this predictor can be calculated by the variance of the series $\left(s_t - f_{t-\tau}\right)$. Thus, the ratio of error variance of these two estimations provides an alternative measure of the efficiency of futures prices as predictors of the expected value of spot prices. Therefore the measure of market efficiency, ϕ_c, has the following representation.

$$\phi_c = \frac{(T-2k-2)^{-1}\sum_{t=1}^{T}\hat{\varepsilon}_t^2}{(T-1)^{-1}\sum_{t=1}^{T}\left[(s_t - f_{t-\tau}) - \left(\overline{s_t - f_{t-\tau}}\right)\right]^2}$$

Where T is the number of observations, and (2k + 2) the number of estimated parameters. Thus, the range of values that can take the efficiency measure is $0 \leq \phi_c \leq 1$ where $\phi_c=0$ represents a complete inefficiency.

4 Empirical analysis

The empirical analysis developed in this paper is structured as follows. First, the market validity hypothesis understood as the fulfillment of the weak-efficiency hypothesis, is investigated by testing the presence of unit roots in the series of spot, futures and forward prices.

Second, the efficiency of futures markets in the short- and long term is analyzed. To this end, the relationship between the price series of futures contracts and the geometric average of the forward curve, as a proxy for spot price proposed by Borovkova and Geman (2008) is studied, using cointegration analysis, VECM models and the market efficiency measure proposed by Kellard et al. (1999).

Finally, the relationships between prices for spot, futures and forward markets are studied by examining the causality between them and trying to determine the lead-lag relationship.

4.1 Market validity hypothesis

The market validity hypothesis reflects the speed and the extent to which the market absorbs new information. The weak efficient hypothesis assumes that (future, forward or spot) prices fully reflect the information available in the market. To verify the weak efficient hypothesis of the market, the assumption of random walk is usually tested. To do so, the analysis of stationarity gives us the tool to check this type of efficiency.

Table 2: Stationarity test (KPSS)

KPSS test contrasts the null hypothesis of stationarity against the alternative hypothesis of non-stationarity using the Lagrange multiplier test.

LFUT_i: logarithm of future contract price expiring i.
LFWD_i: logarithm of forward contract price expiring i.
LSPOT: logarithm of SPEL index price.
Where i = W +1 (week ahead), M +1 (month ahead), Q +1 (quarter ahead) and Y +1 (year ahead).

	Levels		**1st differences**
	KPSS		**KPSS**
LFUT_W+1	0,8063	***	0,0662
LFUT_M+1	0,9845	***	0,0709
LFUT_Q+1	1,2399	***	0,1092
LFUT_Y+1	2,0751	***	0,1432
LFWD_W+1	0,7614	***	0,0585
LFWD_M+1	0,9792	***	0,0716
LFWD_Q+1	0,4126	*	0,1292
LFWD_Y+1	1,9041	***	0,1203
LSPOT	0,8253	***	0,0345

Reject the null hypothesis at 1% (***), 5% (**), 10% (*) of significance level

Table 2 summarizes the results of unit root tests, indicating that the series of spot, futures and forward are non-stationary, while the first differences are stationary. Therefore, the analyzed series are non-stationary in levels, implying that the prices of each market follow a random walk. Hence, the best prediction of tomorrow is today's price ($E(S_{t+1})=S_t$). Thus, the price for today captures all the relevant information meaning that the market validity holds, in other words, that the studied markets are at least efficient in the weak sense. For the Scandinavian electricity market the same conclusions have been achieved by Yang *et al.* (2009) and Feng *et al.* (2007).

4.2 Long- and short-term efficiency analysis

First, we analyze the efficiency of futures market in the long term, by means of testing whether futures prices and the geometric average of the forward curve as a proxy for the spot price are cointegrated. If so, it can be concluded that the futures market is efficient in the long-term. Only monthly and quarterly maturities will be used due to lack of data needed for the construction of the futures series.

As indicated before, the approach of using the geometric average of the forward curve as a proxy for spot price was suggested by Borovkova and Geman (2008), within a context where the traditional *cost-of-carry* model cannot be used. Instead, these authors proposed the *seasonal cost-of-carry* model for non-storable commodities:

$$GA = \sqrt[N]{\prod_{T=1}^{N} Fwd(t,T)}$$

$$F(t,T) = GA \cdot e^{[s(T)-\gamma(t,T-t)\cdot(T-t)]}$$

Where F(t,T) and Fwd(t,T) is the futures and forward price with maturity T at time t respectively, s(T) is a seasonal premium, which is deterministic and depends on the month of expiration, satisfying $\sum_{M=1}^{12} s(M) = 0$, and γ(t,T-t) is the stochastic premium, which should be modeled depending on the studied asset.

According to our results, the series of futures prices for each of the considered maturities (Table 2), as well as the series of the geometric average of the forward curve are non-stationary[14]. The next step will be to check whether they are cointegrated. Cointegration results are shown in Table 3.

It can be observed that the series of 1-month- and 1-quarter ahead futures logarithm prices and the corresponding series of the geometric average of the forward curve are cointegrated. Therefore, we can conclude that MIBEL futures market is long-term efficient for the 1-month-ahead and 1-quarter-ahead futures contracts. These results are consistent with those for Nord Pool futures market in Feng *et al.* (2007) and Yang *et al.* (2009).

Table 3: Cointegration test

Johansen cointegration test is performed by likelihood ratio of λ trace (λ max), being the null hypothesis that the number of cointegration vectors is less than or equal to r (equal to r).

LFUT_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LGA: logarithm of the geometrical average of the forward prices.

	λ trace			**λ max**		
	r = 0		**r ≤ 1**	**r = 0**		**r = 1**
LGA – Lfut_M+1	93,3943	*	3,3216	90,0727	*	3,3216
LGA – Lfut_Q+1	25,8661	*	3,3947	22,47,14	*	3,3947

* Reject the null hypothesis at 5% of significance level

With respect to the short-term efficiency, Table 4 presents the Wald test applied to the short-term coefficients of VECM for the involved futures contracts. The null hypothesis tested is that all coefficients are zero, against the alternative that they are not. If the null hypothesis is not rejected, there is causality in the Granger sense in the short-term between the exogenous variable and endogenous variable.

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[14] KPSS test results are 0,8644 (***) for levels and 0,1015 for differences.

Table 4: Short-term causality analysis.

$$\Delta Y_t = \alpha_1 + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \sum_{j=1}^{p} \delta_j \Delta X_{t-j} + \beta_1 \mu_{t-1} + \varepsilon_{t1}$$

$$\Delta X_t = \alpha_2 + \sum_{i=1}^{p} \gamma_i^{'} \Delta Y_{t-i} + \sum_{j=1}^{p} \delta_j^{'} \Delta X_{t-j} + \beta_2 \mu_{t-1} + \varepsilon_{t2}$$

Optimal lags have been determined by Akaike's information criterion. To test the short-term causality the Wald is being used.

LFUT_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LGA: logarithm of the geometrical average of the forward prices.

Maturity	Endogenous Variable	Optimal lags	LGA		LFUT_i	
			Long term	Short term	Long term	Short term
Month Ahead	LGA	2			Yes	Yes
	χ^2				25,7260 ***	39,8735 ***
	LFut_i		Yes	No		
	χ^2		32,1259 ***	2,2699		
Quarter Ahead	LGA	4			Yes	Yes
	χ^2				25,72598 ***	51,2926 ***
	LFut_i		No	No		
	χ^2		7,99E-05	7,3147		

Reject the null hypothesis at 1% (***), 5% (**), 10 % (*) of significance level

As can be observed in Table 4, the test coefficient indicates that futures price causes in the sense of Granger the proxy for spot price for any maturity. On the contrary, the proxy for spot price does not cause, in the Granger sense, the future price. So, the above results indicate that futures prices drive the (proxy for) spot prices and not vice versa. Hence, the futures market reflects good operating efficiency.

In addition, in order to quantify the degree of efficiency of futures market, Kellard *et al.* (1999)'s market efficiency measure is computed.

Results are presented in Table 5. Although Kellard *et al.* (1999)'s market efficiency measure is higher for the 1-month-ahead futures contract (0,31) than for the 1-quarter-ahead contract (0,16), indicating a higher degree of efficiency associated with the former, however these values are quite low when compared to other electricity markets as Nord Pool (0,47) (Yang *et al.* 2009)[15]. Also, in other

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[15] For the period 2000-2003.

commodity markets such as the soybean, live hogs and live cattle markets Kellard *et al.* (1999) obtain values of 0.87 0.99 and 0.77 respectively for periods 1982-1996 for live hogs and live cattle and 1979-1996 for soybean. In this sense, it should be noted that MIBEL futures market is newly created and may lack the maturity of other more consolidated commodities futures markets.

Table 5: Market efficiency measure.

$0 \leq \phi_c \leq 1$, $\phi_c = 0$ total inefficiency and $\phi_c = 1$ total efficiency.

LFUT_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

Lfut_M+1	Lfut_Q+1
0,3074	0,1568

4.3 Lead-lag relationship within MIBEL markets

In this section, the transmission of information between prices of the three studied markets (spot, futures and forward) is investigated. Thus, lead-lag relationships are analyzed between (i) futures and forward prices, (ii) futures and spot prices and, finally, (iii) forward and spot prices. These relationships will be analyzed by using VECM models as they allow us to examine short- and long-term relationships between the involved price series.

Furthermore, as indicated in the Introduction, it should be noticed that a reiterated recommendation by the CNE is the need for monitoring the prices of the spot, futures and OTC market and their relationships (CNE 2010).

Initially, a graphical view of each pair of series is displayed in figures 1, 2 and 3. As can be observed, futures and forward prices follow a similar. Regarding the future and spot prices and forward and spot prices, the difference is most noticeable in the 1-quarter-ahead maturity, showing that the spot price is more volatile than the quarterly futures price (as mentioned previously), as expected, taking into account that the spot price has one-day delivery period and is computed by the average of the 24 hourly prices resulting from the auctions of the day-ahead market whereas the 1-quarter-ahead price has a quarter delivery period. Therefore, price is obtained as an average of all the hourly prices of all the days included in the quarterly period, and consequently, the series of quarterly futures prices is much more smooth than the series of spot prices.

Figure 1: Future and forward relationship.

Logarithm price of 1-moth-ahead and 1-quarter-ahead of futures and forward contract for July 3, 2006 to April 13, 2011

LFUT_i: logarithm of future contract price expiring i.

LFWD_i: logarithm of forward contract price expiring i.

Where i = M +1 (month ahead), Q +1 (quarter ahead).

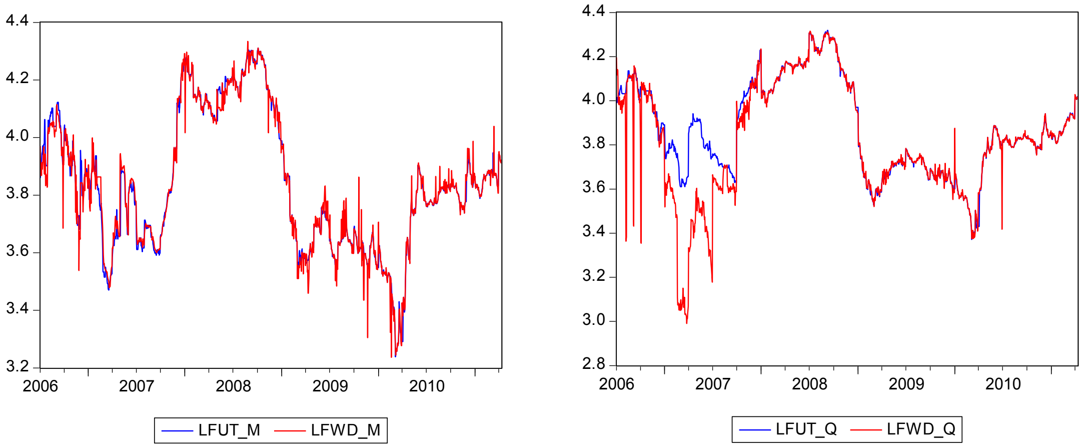


Figure 2: Future and spot relationship.

Logarithm price of 1-moth-ahead and 1-quarter-ahead of futures contract and spot contract for July 3, 2006 to April 13, 2011

LFUT_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LSPOT: logarithm of spot price (SPEL index price).

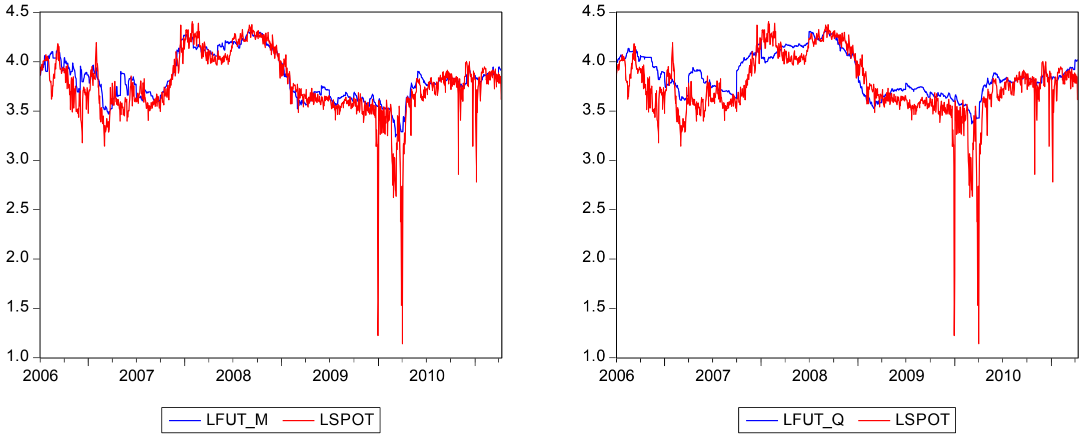
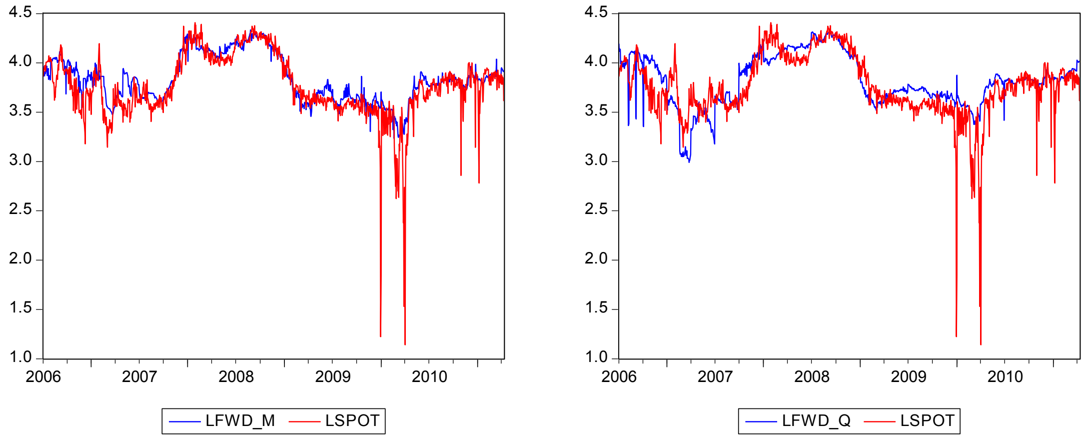


Figure 3: Forward and spot relationship.

Logarithm price of 1-moth-ahead and 1-quarter-ahead of forward contract and spot contract for July 3, 2006 to April 13, 2011

LFWD_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LSPOT: logarithm of spot price (SPEL index price).



In Tables 6, 7 and 8 the lead-lag relationships between all pairs of prices are summarized.

Table 6: Futures and forward price relationship:

Optimal lags have been determined by Akaike information criterion.

LFUT_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LFWD_i: logarithm of forward contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

Maturity	Endogenous Variable	Optimal lags	LFUT_i		LFWD_i	
			Long term	Short term	Long term	Short term
Month Ahead	LFut_i	2			Yes	No
	χ^2				13,6125 ***	0,5724
	LFwd_i		Yes	Yes		
	χ^2		154,3926 ***	35,3847 ***		
Quarter Ahead	LFut_i	3			No	No
	χ^2				1,1625	0,8793
	LFwd_i		No	Yes		
	χ^2		1,7918	13,3870 ***		

Reject the null hypothesis at 1% (∗∗∗), 5% (∗∗), 10 % (∗) of significance level

Table 7: Futures and spot price relationship:

Optimal lags have been determined by Akaike information criterion.

LFUT_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LSPOT: logarithm of spot price (SPEL index price).

Maturity	Endogenous Variable	Optimal lags	LSPOT		LFUT_i	
			Long term	Short term	Long term	Short term
Month Ahead	Lspot	2			Yes	Yes
	χ^2				112,4580 ***	48,4882 ***
	LFut_i		Yes	No		
	χ^2		11,6474 ***	2,8300		
Quarter Ahead	Lspot	2			Yes	Yes
	χ^2				74,6682 ***	26,6376 ***
	LFut_i		No	No		
	χ^2		0,1622	1,4430		

Reject the null hypothesis at 1% (∗∗∗), 5% (∗∗), 10 % (∗) of significance level

Table 8: Forward and spot price relationship:

Optimal lags have been determined by Akaike information criterion.

LFWD_i: logarithm of future contract price expiring i, where i = M +1 (month ahead), Q +1 (quarter ahead).

LSPOT: logarithm of spot price (SPEL index price).

Maturity	Endogenous Variable	Optimal lags	LSPOT		LFWD_i	
			Long term	Short term	Long term	Short term
Month Ahead	Lspot	2			Yes	No
	χ^2				100,3211 ***	2,1365
	LFwd_i		Yes	No		
	χ^2		21,5906 ***	3,7411		
Quarter Ahead	Lspot	5			Yes	No
	χ^2				49,2181 ***	2,3249
	LFwd_i		No	No		
	χ^2		0,4262	4,4010		

Reject the null hypothesis at 1% (∗∗∗), 5% (∗∗), 10 % (∗) of significance level

Looking at the above results, it is obtained that regarding the month-ahead contract, there exists long-term bidirectional causality, i.e. futures prices help to predict forward price and vice versa. In contrast, with regards the quarter-ahead contract, there is no causal relationship in either way in the long-term. Regarding the short-term causality, futures prices help to predict forward prices for both the month-ahead- and the quarter-ahead contracts but the contrary does not hold (Table 6).

Due to the fact that futures and forward contracts with the same maturity share the same underlying asset, one would have expected a bidirectional effect. However, our results inform that this intuition is not true in the short term, as futures prices cause forward prices but not in the other way. A possible explanation of this may be an indicative of the correct price formation in the futures market as the agents may be relying on the price of this market and even base their biddings to the forward market on it.

Regarding the relationship between forward and futures prices and spot prices[16], Table 7 shows that there is bidirectional causality in the long term between futures and spot prices in the monthly maturity. In contrast, for the quarterly maturity futures prices help to predict spot prices, but not vice versa. With regards to the short term, there is a unidirectional causality from the futures price to spot price. This conclusion could be expected because a function of the futures is to give an approximation of the spot price at the expiration.

Finally, Table 8 summarizes the causal relationship between forward and spot prices. Thus, for 1-month-ahead contract, there exists bidirectional causality between the forward 1-month-ahead and spot prices in the long term; on the other hand, with respect to 1-quarter-ahead contract, there exists unidirectional causality from forward to spot prices. In contrast, in the short term, there is no causal relationship between forward and spot prices for any of the two studied contracts.

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[16] These relationships must be understood as a mere empirical evidence of the relationship between markets, although there is no theoretical basis to support them.

There is unidirectional causality from futures and forward prices to spot prices, meaning that there is a lead-lag relationship between futures and spot prices, that is, the futures market drives the spot market and not vice versa. Thus, in MIBEL futures market, the futures market plays a leading role in the price discovery function, reflecting good operating efficiency. In this sense, similar resuls are obtained in Yang *et al.* (2009) and Feng *et al.* (2007) for the Scandinavian market.

5 Conclusions

This paper focus on analyzing the relationships between (futures and OTC) forward prices with maturities of one month- and one quarter- ahead and spot prices for electricity related to Spanish area, over the period 2006-2011. Of this analysis the following main results are emphasized: (i) the futures market and the day-ahead market of MIBEL verify the weak efficiency hypothesis, i.e. the validity of the market is achieved. (ii) MIBEL futures market is efficient in the long-term, (iii) causal relationships are noted in the short term from futures price to the geometric average of the forward curve as a proxy for spot price and (iv) it has been shown lead-lag relationships between the three pairs of studied series. Futures price have an impact on forward prices for the monthly and quarterly maturities, what is indicative of a reliable price formation process in the futures market. Thus, market participants would be confident in the future price and would even rely on it to bid in the forward market. Additionally, empirical evidence of unidirectional Granger causality from one-month-ahead- and one-quarter-ahead futures prices to spot prices is obtained, indicating that the futures market plays a leading role in the price discovery function.

These conclusions provide relevant information about the relationships of three important markets coexisting in MIBEL, covering the need pointed out by the CNE about the study of the relationship of the different markets within MIBEL. Also, this research evidences that, despite the greater volume of the OTC forward market, futures prices seem to lead forward prices. Moreover, in a context of high volatility of the financial and commodities market, the achieved conclusions are of relevance also practitioneers when desigining their trading strategies.

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