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Expectations and forward risk premium in the Spanish power market*

Dolores Furió and Vicente Meneu**

Abstract

To analyse the forward risk premium in the Spanish electricity market, we adopt not only an *ex post* approach, but also an *ex ante*. We find that the sign of the *ex post* forward premium depends on the unexpected variation in demand and on the unexpected variation in the hydro-energy capacity, and that the *ex ante* forward premium varies with the expected demand in tight market conditions, showing that the participation of forward dealing agents in the Spanish market responds to risk considerations. Moreover, we find support for the implications derived from the Bessembinder & Lemmon (2002) equilibrium model.

Jel Classification

G13; L94; G18

Keywords

Ex post forward premium, ex ante forward premium, spot price estimation, hedging needs.

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1. INTRODUCTION

The study of the relation between forward and spot prices has been the main topic of many theoretical and empirical papers. The cost-of-carry relationship links spot and forward prices as a non-arbitrage condition. However, the implementation of arbitrage strategies includes taking the underlying asset and holding it until the contract expiration date. In the case of electricity, this matter becomes particularly difficult to address due to the fact that the electricity cannot be virtually stored1. This means that the non-arbitrage approach to pricing derivative securities cannot be applied in the usual manner (Eydeland & Geman, 1998; Bessembinder & Lemmon, 2002; Lucia & Schwartz, 2002; Longstaff & Wang, 2004 and Pirrong & Jermakyan, 2005).

Another general approach to price forward contracts, used in the literature as an alternative to the arbitrage value theory, is based on equilibrium considerations. Bessembinder & Lemmon, 2002 (henceforth, B-L) adopt this approach and model the economic determinants of market clearing forward power prices. Their model assumes that prices are determined by industry participants rather than outside speculators, and that power companies are concerned with both the mean and the variance of their profits. One of the implications of the model is that the forward power price is a downward biased predictor of the future spot price – if expected power demand is low and demand risk is moderate. However, the equilibrium forward premium increases when either expected demand or demand variance is high, because of a positive skewness in the spot power price distribution. Another directly testable result is that the forward risk premium (defined as the difference between the forward and spot price) depends negatively on the variance of the spot price variance and positively on the skewness of the spot price. In the second part of their paper, B-L generally present empirical evidence on the theoretical results commented above. The data in their study consists of a set of spot and monthly electricity forward prices from the Pennsylvania, New Jersey, and Maryland (PJM) electricity market and from the California Power Exchange (CALPX). Cartea and Villaplana (2008) propose a model where wholesale electricity prices are explained by two state variables: demand and capacity. They apply their model to the PJM, England and Wales and Nord Pool markets and observe that the forward premium dynamics are seasonal.

Other papers directly focus on the empirical analysis of the risk forward premium. For example, Shawky et al (2003) conclude non-zero premium in the California-Oregon border.

[1] Though power is not storable, potential energy can be stored in the form of fuel stockpiles or water behind dams.

Lucia and Torró (2006) contrast the implications of the B-L model, specifically, the implication that links the risk forward premium and the volatility of the spot price using weekly electricity contracts from Nord Pool. These authors also show the importance of water reserves to explain the dynamics of the premium through a VAR model. Ullrich (2007) proposes an extension to the B-L model to account explicitly for constrained capacity. According to his results, the behaviour of the forward premium depends on whether the level of the expected spot price is greater or lesser than the fixed retail electricity price. Finally, Benth et al. (2007) provide a framework to explain the relation between the forward premium and the risk preferences of market players – as well as the interaction between buyers and sellers.

In some studies the day-ahead electricity contract price has been chosen as the forward price for analysing the risk forward premium. This is the case of Geman and Vasicek (2001) who conclude the existence of asymmetrically positive premiums in the PJM market for the summer months. Without changing markets, Longstaff and Wang (2004) conduct an empirical analysis of the forward risk premium using hourly prices. They discover there are significant electricity forward premiums and that these premiums vary systematically throughout the day and are directly related to economic risk factors, such as the volatility of unexpected changes in demand, spot prices, and total revenues. They also test some of the empirical implications derived from the Bessembinder & Lemmon model, concluding that they are supported by the data. Karakatsani and Bunn (2005) determine systematic patterns in day-ahead forward premiums after classifying half-hourly trading periods into two homogeneous peak and off-peak clusters.

This study intends to conduct an empirical analysis of the presence of risk in both *ex ante* and *ex post* forward premium in the Spanish electricity market. The price series database consists of a set of (day-ahead) spot prices and next month (NM, henceforth) forward OTC monthly electricity prices – whose maturity period is extended over the following month.

This paper contributes to the literature on the empirical analysis of risk in forward electricity premiums by adopting not only the *ex post* approach but also the *ex ante* and so enabling an enriched analysis. To build the series of *ex ante* forward premium, we first need to estimate the future spot price. Consequently, another contribution of this paper is the proposal of an estimation model for electricity spot price. We present the fundamentals that explain the Spanish electricity forward risk premium, evidencing that market players trade forward contracts according to risk considerations. Our results also suggest that market agents have built into their cost structure the CO_2 emission allowances prices. Moreover, we find support for the implications derived from the B-L model. Finally, we would like to note that this study analyses the forward risk premium in the Spanish electricity market for the first time.

The main results are as follows. First, the *ex post* NM forward premium depends on the unexpected variations in demand under tight market conditions, and on the unexpected variations in the level of hydroelectric energy capacity. Second, by estimating the proposed spot price model, we find two new interesting insights related to pricing in the Spanish electricity market. On one hand, electricity prices are linked to CO_2 emission allowances prices. On the other hand, prices have not been affected by the new market matching rules introduced in the spot market in March 2006. Third, regarding the dynamics of the *ex ante* premium, we obtain the result that it varies with the expected demand in times of scarce hydro capacity. Fourth, as the B-L model predicts: (i) the *ex post* NM premium is positively related to the skewness of the spot price, while negatively related to the volatility of the spot price; and (ii) the *ex ante* NM forward premium depends negatively on the spot price variance, increases with mean demand and is initially decreasing and then increasing in demand risk.

The remainder of this paper is organized as follows. Section 2 briefly describes the structure of the Spanish electricity spot market and discusses the importance of hydro energy capacity in the Spanish electric system. Section 3 describes the data used. Section 4 provides some insights into the theoretical background of the risk forward premium. Section 5 is concerned with the variables that may explain the *ex post* premium and tests whether the B-L model implications are supported by data. In section 6, we propose a regression model to estimate the series of expected spot prices and forecast NM spot price. In section 7, the series of *ex ante* forward premium is derived using spot price predictions from the above mentioned regression model, and the B-L model predictions are tested. Finally, section 8 summarizes the results and concludes.

2. THE SPANISH ELECTRICITY SPOT MARKET

The Spanish electricity spot market is organized into two markets: a day-ahead market where participants submit offers to sell and bids to purchase electricity for delivery at any specified hour during the subsequent day, and an intra-day market, which is defined as an adjustment market in which agents may rectify their previous positions. Over the counter, physical bilateral contracting is also allowed– although bilateral agreements have to be communicated so as to facilitate the system's technical management2.

The day-ahead market and the intra-day market both work as uniform-price electronic auction markets. Prices are determined according to the marginal-price criteria. Thus, the

[2] From January 2000 to December 2005, bilateral trades remained close to 1% of the total electricity traded in the day-ahead market.

intersection between both curves determines the merit-order dispatch – as well as the marginal price (i.e. the price for the last accepted supply bid) for each hour.

On the 3rd March 2006 a new regulation on market matching rules came into effect3 for both the day-ahead and intra-day markets. It introduced a substantial variation in the amount of electricity that actively takes part in the price determination process. To be more specific about the details of this new regulation, it should be noted that, though transitorily, particularly until the 27th February 20074, the bids to sell and purchase electricity that are simultaneously submitted to the market by entities belonging to the same enterprise group (for delivery during the same hourly horizon) are assimilated into physical bilateral trades for the coincident amount of offered electricity. Thus, after this market reform, only the net position of each enterprise group resulting from this assimilation process, which can be either positive or negative, participates actively in the price determination process.

The supply curve in electricity markets is relatively flat when demand is lower than the available capacity of baseload units and it increases sharply when demand exceeds such capacity. This is also known as the supply stack, since the different technologies used to generate electricity are stacked in order of increasing production variable costs. At the bottom are the least expensive units which include hydroelectric, renewable resources (wind, solar, etc.), nuclear and coal plants, while fuel oil-gas plants and CCGT plants are often at the top of the stack supply.

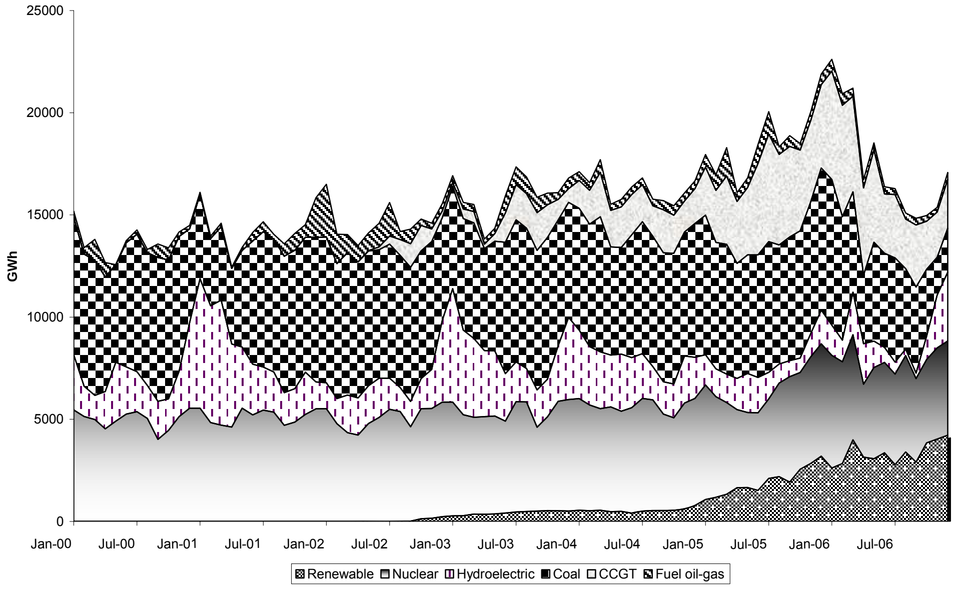
The generation mix of the Spanish electricity system is made of renewable resources (26% of total capacity in 2006), hydro power (21%), CCGT (20%), coal (15%), nuclear (10%) and oil-gas (8%)5. Installed capacity in renewable sources has experienced a noticeable increase, being 268 per cent higher than ten years ago. Electricity production in 2006 was about 271000 GWh – produced by coal (24%), CCGT (23%), nuclear (22%), renewable (19%), hydropower (9%) and fuel oil/gas (2%). Figure 1 below depicts the monthly evolution of electricity generation in the Spanish electricity wholesale market from 2000 to 2006 – by technology type.

As can be seen from Figure 1, demand has shown a noticeable growth over the displayed period. It is also remarkable that the evolution of hydroelectricity seems to be opposite to that of fuel-oil gas, coal-fired, and CCGT-based production. This visual inspection is confirmed by correlation coefficients between hydroelectric and fuel oil-gas production of -0.36, hydroelectric and coal-fired production of -0.43, and hydroelectric and CCGT of -0.54.

[3] Royal Decree-Law 3/2006.
[4] This is the date when Ministerial Order ITC/400/2007 regulating bilateral trading for distributors came into force.
[5] Data source: 2006 annual report (REE). www.ree.es

This fact reveals that hydro technology could play a significant role in spot price formation, since it can meet the demand for electricity by substituting more expensive technologies.

Figure 1. Electricity production by technology type in the Spanish (day ahead) spot market (January 2000 – December 2006)



Data source: OMEL.

Therefore, the greater the availability of hydro energy, the lower the need for high production variable cost units to be dispatched. Consequently, in absence of market power, low (high) prices should be expected in situations of plentiful (scarce) hydro capacity, and, in that sense, this variable could be used as a proxy for Spanish supply market conditions.

3. DATA DESCRIPTION

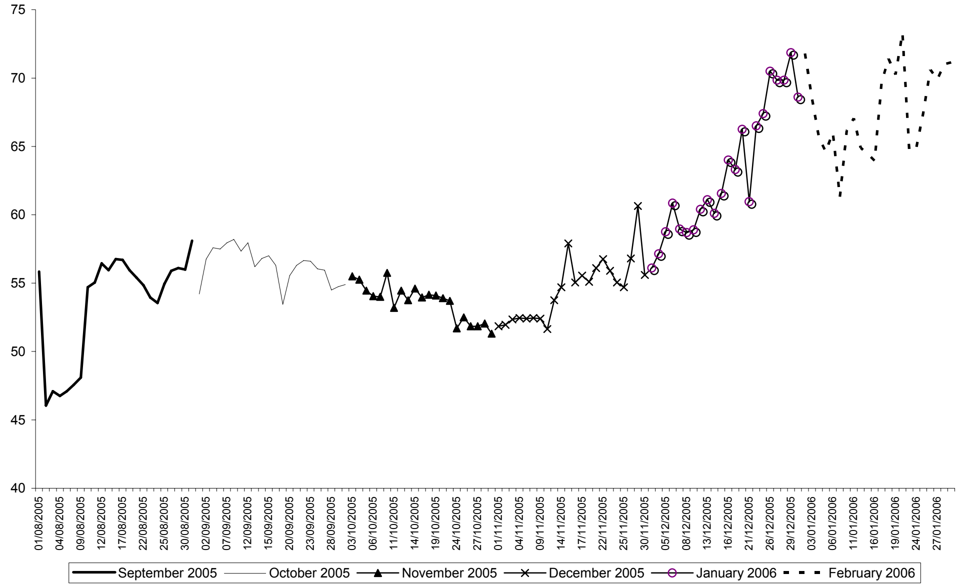
The primary data for this study consists of monthly average OTC forward and spot prices from the Spanish electricity market.

The forward data set includes the business day prices for power to be delivered during 24 hours a day for the next month. Therefore, dealing in an NM contract in January means trading the electricity to be delivered over the 24 hours of every day in February. The spot reference price used for settlement at maturity is the arithmetic mean of day-ahead hourly prices over 24 hours of the day.

As an example, Figure 2 graphs the daily evolution of NM forward prices from 1st August 2005 to 31st January 2006. As it may be noticed, only one maturity can be traded each month. Forward databases are provided by Reuters. The data covers the period 4th February

2003 to 31st January 2007[6]. A subsequent maturity monthly forward contract is traded from the first day of each month, so it is not possible to simultaneously negotiate more than one contract maturity in the same day.

Figure 2. Evolution of the daily NM forward quotes over the trading period August 2005-January 2006
Prices are quoted in Euros/MWh



As said, the data set also includes the spot price for each of the 24 hours of each day from January 2000 to February 2007. Data is available at the OMEL web site (www.omel.es).

Also included are CO_2 emission allowances futures contract prices from Climate European Exchange (CEX). These data can be easily downloadable from the CEX website (http://www.europeanclimateexchange.com). As this contract has only been traded since 22nd April 2005, data is available from that date onwards. The series comprises business days from 22nd April 2005 to 27th February 2007.

Finally, the data set contains monthly hydroelectric energy capacity[7] figures, the series of actual monthly demand as well as the series of monthly expected demand figures for the period January 2000 to February 2007. The first series and part of the second are available at the Red Eléctrica de España (REE) website (www.ree.es), concretely in the annual reports in

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[6] Therefore, we deal with a total of 1034 observations since we have no forward price for eight (0.7% left) days from the overall sample period.
[7] The energy capacity or potential energy of a hydroelectric head installation during a given period of time is defined by REE as the maximum quantity of electrical energy which all the observed corrected inflows, limited to the plant capacity flow, would enable the plant to produce under the most favourable conditions.

the area of publications on electric system operation, while the historical data of expected demand has been provided to us directly by REE.

As can be seen in Table 1, the maximum average spot price is higher than the maximum average forward prices, and the minimum average spot price is lower than the corresponding forward. This fact seems to indicate that the spot price series presents more extreme values than the forward price and that these extreme values are positive, according to the positive value of the exhibited skewness. The variability of prices is also higher for the spot price series as the standard deviation indicates.

Table 1. Descriptive statistics of the forward and spot average monthly price from the maturity period April 2003 through February 2007
Prices are quoted in Euros/MWh

	Forward NM	Spot market
Mean	40.54	40.74
Median	36.87	37.79
Maximum	67.67	73.14
Minimum	25.83	21.46
Standard Deviation	11.74	14.02
Skewness	0.54	0.52
Kurtosis	2.15	2.49

4. THEORETICAL BACKGROUND OF THE FORWARD PREMIUM

Generally speaking, the forward premium is considered in the literature as the equilibrium compensation for bearing spot price risk for the underlying commodity during the period until the maturity of the contract. In the case of electricity, price risk becomes very important, since spikes tend to occur quite frequently and then prices rapidly revert to normal levels. If there are no inventories, this is the market answer to shocks in demand and/or supply.

The forward premium is commonly defined under two perspectives in the studies that empirically analyse their existence. Thus, although some authors use the *ex ante* (Cartea & Villaplana, 2008) or both the *ex ante* and *ex post* forward premium definitions (Bessembinder & Lemmon, 2002; Karakatsani & Bunn, 2005), most researchers directly work with the *ex post* forward premium.

The *ex ante* forward premium is defined as the difference between the forward price and the expected spot price. The *ex post* (or realized) forward premium is computed as the difference between the forward price and the observed spot price.

$$\textit{Ex ante} \text{ forward premium: } \overline{FP_{tT}} = E_t(F_{tT} - S_T) = F_{tT} - E_t(S_T) \quad (1)$$

$$\textit{Ex post} \text{ forward premium: } FP_{tT} = F_{tT} - S_T \quad (2)$$

where F_{tT} denotes the electricity forward price observed on day t for delivery over month T, S_T denotes the monthly average spot price for delivery over month T, and E_t is the expected value conditioned by the information available.

Working with the *ex post* (or realized) premium implies assuming that the *ex post* premium can be expressed as the *ex ante* premium plus random noise. A relation between both premium definitions can be obtained by substituting the expression for F_{tT} from (1) in (2). Thus,

$$F_{tT} - S_T = \overline{FP_{tT}} + E_t(S_T) - S_T \quad (3)$$

According to (3), the *ex post* premium equals the *ex ante* forward premium plus a residual term uncorrelated with variables in the information set at time t. Therefore, working with the *ex post* premium means that prediction errors for the expected spot price (at day t) are assumed to be random noise, or that agents are rational in the sense that prediction errors are not correlated with the available information at t.

5. EX POST FORWARD PREMIUM

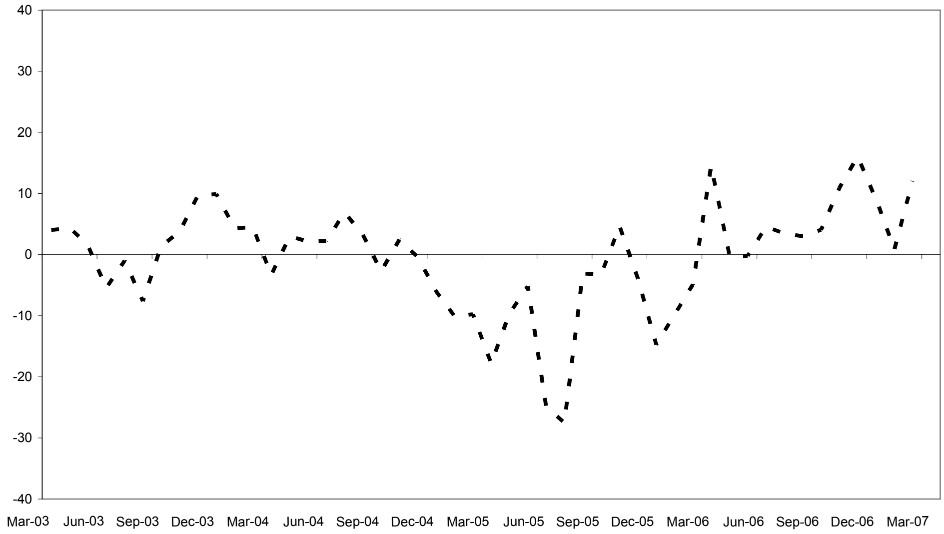
5.1. Magnitude and sign of the *ex post* forward premium

The *ex post* forward premium is obtained as the difference between the monthly average (arithmetic mean) business day forward quotes for electricity to be delivered over a determined maturity month, and the monthly average spot price corresponding to that maturity month. Figure 3 shows the evolution of the *ex post* NM forward premium during the studied period covering the maturity months from March 2003 to February 2007.

We test the presence of non-zero *ex post* forward premium for the electricity NM forward contracts. To do so, we use the following regression to obtain α, as it is the value of the mean forward premium, and then we test the null hypothesis, H_0: $\alpha = 0$, as opposed to the alternative H_1: $\alpha \neq 0$.

$$F_{tT} - S_T = \alpha + \varepsilon_t$$

Figure 3. Monthly ex post NM forward premium (Maturity period: March 2003 – February 2007)



We find that the overall mean of the NM forward premium is -0.53 Euros/MWh and that this is not statistically significant, which *a priori* suggests that there is no statistical evidence for electricity forward premium during the studied period. However, going back to Figure 3, it can be observed that the difference between the forward price and the observed spot price has been persistently negative over the period from November 2004 to February 2006. For the remainder of the sampling period, there seems to be a positive mean forward premium. Hence, the above mentioned result, consistent with the absence of forward premium, could arise from the compensation of positive and negative price differences.

To confirm this, we repeated the tests by separating the period into two sample subperiods: November 2004 to February 2006, and the remainder. The results are shown in Table 2.

Table 2. Unconditional test for the presence of realized forward premium in electricity forward prices

$$F_{tT} - S_T = \alpha + \varepsilon_t$$

	Sample	
	November 2004 - February 2006	March 2003 - October 2004, and March 2006 - February 2007
α	-9.17	3.78
t-Statistic	*-3.91*	*3.17*

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances

Thus, when we look at the results for each of the subsamples separately, we find evidence of significant forward premium. In particular, the mean forward premium is negative (-9.17 Euros/MWh), and statistically significant for the first defined sampling subperiod, while it is positive (3.78 Euros/MWh), and statistically significant for the second subperiod.

In that sense, sign changing premiums have been identified in previous works. Thus, Longstaff & Wang (2004) find that the forward premium varies systematically throughout the day: that it can be both positive and negative, and is related to economic risk factors. Karakatsani & Bunn (2005) reveal a diurnal reversal in the sign of the forward premium. This, as the authors state, reflects the asymmetric positions of generators and suppliers towards risk and its variation within the day – and that such a variation is induced by the intra-day heterogeneity of plant technical characteristics and constraints, as well as aspects of market design. The difference in flexibility between the supply and demand sides of the electricity market has also been pointed out by Botterud et al. (2002). While Benth et al. (2007) and Cartea & Villaplana (2008) argue that it is differences in the desire to hedge positions and diversify risk that explain the market risk premium and its sign.

In particular, generators could have the ability to manage their price risk by exploiting various parameters, such as plant portfolio (using more or less flexible generation plants depending on market circumstances) and other aspects such as degree of horizontal integration, or even market rules (i.e. uniform pricing auction scheme). In contrast, suppliers without generation capacity are directly exposed to price risk and retail demand. The latter is quite inelastic to price in the short term and it is very complex to predict – as opposed to aggregated demand. Consequently, a greater demand for buying forward contracts8 could be expected and, *ceteris paribus,* this higher demand pressure would imply a relative increase in forward prices with respect to spot prices – and then the mean forward premium would be expected to be positive. It should be noted that this statement is only true under the hypothesis that the forward premium is determined by physical participants motivated by hedging, conversely to purely financial speculative positions.

Moreover, another possible explanation for finding the sign of the forward premium to be different during some periods might be the possibly heterogeneous hedging needs met by producers, depending on the differing plant technical characteristics used to generate electricity. In fact, since market prices are determined using a uniform-price auction based on marginal price, it makes intuitive sense that units with low variable costs (eg. hydroelectic, nuclear, or coal-fired plants) might not be exposed to price risk as much as other operating plant technologies such as fuel oil-gas or combined cycle. The managers of such generating

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[8] The higher demand pressure is a result of both the greater quantity of demand and the higher purchase prices offered.

plants additionally have to face their fuel (oil-gas, fuel) price risk, since prices of their inputs are also uncertain due to the fact that these inputs belong to liberalised sectors with non-regulated prices. Due to these considerations, it would be expected that certain generators have a greater incentive to engage in forward transactions in order to hedge, totally or partially, their positions in the spot market.

On one hand, the difference in flexibility on the supply and demand side of the electricity market leaves the demand side with a higher incentive for hedging in futures contracts. On the other hand, the diverse hedging needs and preferences among the different generating technology plants must also be taking into account. Below we examine some of the factors that can be generally helpful in explaining the deviation between spot and futures prices.

5.2. Discussion

To better understand the properties of the premium included in electricity forward prices, we analyse whether variables such as unexpected variations in levels of hydro-energy capacity or unexpected variations in demand contribute to explaining the evolution of the premium.

We compute the difference between the level of hydroelectric energy capacity registered in the maturity month (T) of the forward contract – and the level of hydroelectric energy capacity registered in the current month (t), as a proxy of the former. The obtained series can be interpreted as the unexpected variation in the level of hydro-energy capacity.

The series of unexpected demand is similarly built by subtracting the expected demand for the maturity month from the actual demand registered in that maturity month. However, high levels of expected demand could have a null effect on price movements if they coexist with sufficient supply of electricity to cover demand, so we force the unexpected demand to be zero whenever the level of expected hydroelectric energy capacity is higher than its historical (monthly) mean value.

As a robustness check on the above considerations, we regress the forward premium on the mentioned series of unexpected variations in hydroelectric energy capacity, and of unexpected positive variations in demand, whenever the level of hydroelectric energy capacity is low. The estimation results are shown in Table 3.

The results confirm our intuition since the *ex post* forward premium reacts systematically to the series of unexpected variations in the mentioned factors. Thus, the realized forward premium decreases with unexpected variations in demand ($\beta_1<0$). In fact, if the situation is such that the actual demand exceeds the expected demand for a determined maturity month under tight market conditions, then the actual spot price will probably be higher than expected by agents when trading forward contracts, and this would reduce the forward premium. On the other hand, the realized forward premium increases with unexpected variations in the level of hydro-energy capacity ($\beta_2>0$). Similarly, if the actual level of hydroelectric energy capacity is higher than expected for a given maturity month, then the actual spot price will probably be lower than the spot price anticipated by agents when trading the forward contracts – resulting in a higher forward premium.

Table 3. Results from regression of realized forward premium on unexpected demand and on unexpected hydroelectric energy capacity (March 2003 – February 2007)

$$F_{T,t} - S_T = \alpha + \beta_1 un\exp\_dem_T + \beta_2 un\exp\_hydcap_T + \varepsilon_T$$

	α	β_1	β_2
Coefficient	0.005	-0.003	0.003
t-Statistic	*0.002*	*-2.218*	*2.368*

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

As previously reported, a directly testable result from the B-L model is that the forward premium depends negatively on the spot price variance, and positively on the non-standardised skewness of the spot price. To test this result, we obtained the variance series (VAR) and the non-standardised asymmetry series (ASIM) of the daily spot price (monthly average of day-ahead hourly spot price observations) for each maturity month. The following regression is implemented:

$$F_{t,T} - S_T = \alpha + \beta VAR(S_T) + \gamma ASIM(S_T) + \varepsilon_T \qquad (4)$$

Results confirm B-L predictions. The coefficient for the variance of the spot price, β, is negative and significant, while γ is positive and also significant, which denotes that *ex post* forward premium is negatively related to the variance of spot prices – but depends positively on the asymmetry of spot prices. If we regress the *ex post* forward premium on the spot price variance and on the spot price skewness across seasons, we obtain the result that the forward premium is negatively related to the variance of the spot price in all the seasons but it is positively related to the skewness of the spot price only in Spring and Summer (Table 4).

Table 4. Regression of ex post forward premium on the variance and asymmetry of spot prices (March 2003 – February 2007)

$$F_{t,T} - S_T = \alpha + \beta VAR(S_T) + \gamma ASIM(S_T) + \varepsilon_T$$

	α	β	γ	R^2
All Seasons				
Coefficient	5.06	-0.12	4.60	44.64%
t-Statistic	*3.09*	*-4.06*	*2.88*	
Spring				
Coefficient	3.34	-0.11	9.74	73.31%
t-Statistic	*3.25*	*-10.17*	*2.95*	
Summer				
Coefficient	3.56	-0.13	7.73	52.36%
t-Statistic	*1.39*	*-2.25*	*2.55*	
Fall				
Coefficient	12.86	-0.22	3.80	74.24%
t-Statistic	5.78	*-7.38*	1.35	
Winter				
Coefficient	4.65	-0.12	0.24	0.00%
t-Statistic	*1.20*	*-2.18*	*0.16*	

Note: Regarding results reported across seasons, Spring is defined as the months March, April and May, and the other seasons defined similarly using consecutive three-month periods. The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

6. SPOT PRICE ESTIMATION

6.1. Spot price model

To deal with *ex ante* forward premiums it is necessary to obtain the expected spot prices for the maturity month. In particular, expected spot prices for the next month are needed to compute NM forward *ex ante* premiums, respectively. With that aim, we propose a model to infer the future spot price from available information on supply and demand.

Because the spot price results from an auction based on marginal price, a variation in demand is not, in itself, sufficient to provoke a variation in price. Moreover, because there can be no inventory, the spot price of electricity is determined not only by the level of demand, but also by the total amount of supply (Ullrich, 2007).

Our model contains information not only from demand-side but also from supply-side variables. As indicated above, in the Spanish system, during dry periods, the scarce water reserves lead to the replacement of hydroelectric generation by combined cycle and fuel oil-gas electricity production. Thus, low levels of hydroelectric energy capacity can be used as an indicator of a situation where other (peaking) units probably need to be dispatched and if so, the spot price will consequently react. Other units with relatively low variable cost are nuclear and coal-fired plants, but their capacity remains quite stable. Therefore, we approximate the available supply from the least variable cost units with the level of hydroelectric energy capacity.

Thus, we consider the ratio of expected demand to expected hydro-energy capacity for the corresponding maturity month as an explanatory variable for the future spot price. This variable allows us to capture the interaction between demand and supply, since the effect of the expected demand on price will also depend on the baseload system capacity approximated here with the level of hydro-energy capacity.

In addition, as a consequence of the commitment assumed by Spain with regard to the greenhouse effect, an additional cost is introduced from 2005 onwards in the electricity generation process of those plants that emit CO_2 to the atmosphere. This cost reflects the required inclusion of emissions prices into the cost structure of such plants. We suggest incorporating into the model the information on the effects of CO_2 emission allowance prices on electricity prices.

Also included are other variables, such as a dummy variable to distinguish the period prior and after the introduction of the previously commented new matching rules and eleven monthly seasonal dummy variables. The reason for including only eleven dummy variables, when there are actually twelve months, is to avoid multicollinearity problems.

We propose the following estimation model based on GARCH(1,1) to control for heteroskedasticity:

$$\ln(P_t) = \alpha + \beta \ln(P_{t-1}) + \varphi \ln(\exp\_dem_t / hydro - cap_{t-1}) + \gamma \cdot co2_{t-1} + \theta \cdot rd3_t + \sum_{k=1}^{11} \lambda_k m_{kt} + u_t$$

$$h_t = a + bh_{t-1} + cu_{t-1}^2 \qquad (7)$$

where $\ln(P_t)$ denotes the logarithm of the monthly average spot price for the month t; $\ln(\exp\_demand_t / \text{hydro-cap}_{t-k})$ denotes the logarithm of the ratio of the expected demand to the last available hydro-energy capacity (namely the t-1 month, as a proxy for the expected hydro-energy capacity for the month "t"); the expected CO_2 emission allowance price is approximated by the last available monthly emission price; $rd3_t$ is a dummy variable that takes the value 0 if t is prior to March 2006, and 1, in other cases; m_{kt} is a dummy variable that refers to each month of the year, with the exception of January (the omitted month is the reference category, as the other coefficients must be interpreted by referring to it) and h_t is the conditional variance of the logarithm of the monthly electricity price.

Table 5. Model estimation results (January 2000 – February 2007)

$$\ln(P_t) = \alpha + \beta \ln(P_{t-1}) + \varphi \ln(exp\_dem_t / hydro - cap_{t-1}) + \gamma \cdot co2_{t-1} + \theta \cdot rd3_t + \sum_{k=1}^{11} \lambda_k m_{kt} + u_t$$

$$h_t = a + bh_{t-1} + cu_{t-1}^2$$

	Coefficient	*(t-Statistic)*
α	1.46	*(5.62)*
β	0.47	*(5.2)*
φ	0.22	*(5.26)*
γ	0.01	*(3.01)*
θ	-0.02	*(-0.35)*
λ_2	-0.05	*(-0.6)*
λ_3	-0.13	*(-1.66)*
λ_4	-0.11	*(-1.58)*
λ_5	-0.04	*(-0.49)*
λ_6	0.10	*(1.42)*
λ_7	-0.14	*(-1.74)*
λ_8	-0.47	*(-5.06)*
λ_9	-0.33	*(-1.98)*
λ_{10}	-0.40	*(-3.57)*
λ_{11}	-0.24	*(-2.41)*
λ_{12}	-0.17	*(-2.71)*
a	0.01	*(0.66)*
b	0.20	*(0.19)*
c	0.18	*(0.78)*
	R^2	0.84
	Akaike info criterion	-0.76
	Schwarz criterion	-0.21
	n	85

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

The estimation results for the entire data set are displayed in Table 5. Model reveals a satisfactory R-squared figure of 84%, signifying that much of the spot price is predictable. As can be seen in the estimation output, the coefficient for the ratio of the expected demand to the expected hydro-energy capacity is significantly positive, indicating that the electricity price is an increasing function of this indicator of market demand and supply conditions. The coefficient for the CO_2 emission allowances price is also positive and significant, which suggests that market agents have built into their cost structure the CO_2 emission allowances prices. Finally, we obtain no direct effect on price of the new matching rules introduced by the RD-L 3/2006, as indicated by the non-significance of θ.

6.2. Expected spot price

Two alternative approaches are used in this paper to construct forecasts for the future spot price. First, an out-of-sample interval (March 2006 – February 2007) is chosen and then model coefficients are estimated using only observations from March 2003 – February 2006. Then, forecasts for every period of the out-of-sample interval are computed using the coefficients resulting from the first estimation.

As an alternative method of proceeding, in forecast procedure 2 the estimation sample is extended by one observation, then the model is estimated again and a forecast for the next period of the out-of-sample interval is obtained. This procedure is repeated until forecasts for each period of the forecast sample have been computed.

The estimation results for the estimated price are shown in Table 6. Conclusions are maintained and the goodness of fit is even improved according to R-squared, Akaike and Schwarz criteria.

Table 6. Model estimation results (January 2000 – February 2006)

$$\ln(P_t) = \alpha + \beta \ln(P_{t-1}) + \varphi \ln(exp\_dem_t / hydro - cap_{t-1}) + \gamma \cdot co2_{t-1} + \sum_{k=1}^{11} \lambda_k m_{kt} + u_t$$

$$h_t = a + bh_{t-1} + cu_{t-1}^2$$

	Coefficient	*(t-Statistic)*
α	1.68	*(7.44)*
β	0.36	*(4.93)*
φ	0.29	*(7.1)*
γ	0.01	*(4.18)*
λ_2	-0.04	*(-0.77)*
λ_3	-0.14	*(-1.68)*
λ_4	-0.11	*(-1.71)*
λ_5	-0.04	*(-0.59)*
λ_6	0.10	*(1.35)*
λ_7	-0.14	*(-1.74)*
λ_8	-0.62	*(-6.17)*
λ_9	-0.52	*(-4.2)*
λ_{10}	-0.49	*(-4.75)*
λ_{11}	-0.25	*(-2.57)*
λ_{12}	-0.18	*(-2.74)*
a	0.01	*(1.36)*
b	0.42	*(0.76)*
c	-0.20	*(-1.89)*
	R^2	0.88
	Akaike info criterion	-1.05
	Schwarz criterion	-0.49
	n	73

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

We obtain very similar results when varying the estimation sample by including a new observation with the estimation procedure 2. For comparative purposes, Table 7 displays the estimated one-month-period spot prices using the above mentioned alternative estimation procedures, together with the actual spot price for the forecast period March 2006 to February 2007.

Table 7. Actual and Estimated NM price (March 2006 – February 2007)

	Actual spot price	Estimated spot price	
		Forecast procedure 1	Forecast procedure 2
March-06	65.00	58.55	58.55
April-06	50.15	44.67	40.60
May-06	48.84	52.45	52.32
June-06	51.49	59.75	57.50
July-06	53.94	73.82	68.77
August-06	49.13	42.14	37.93
September-06	56.52	46.41	48.97
October-06	55.25	43.78	45.05
November-06	52.54	34.46	34.96
December-06	45.12	28.18	29.26
January-07	46.66	30.35	33.67
February-07	47.97	42.23	49.34

Focusing on the estimated NM spot price, both estimated prices are very close to each other for most of the sample months – although it seems that distances from estimated prices using the estimation procedure 2 and actual prices are lesser. This suggests that the estimation procedure 2 leads to slightly better forecasts. On the following section, because identical conclusions are achieved, we only present the results of computing the series of *ex ante* forward premiums with estimated prices using the estimation procedure 1.

7. EX ANTE FORWARD PREMIUM

The *ex ante* forward premium is obtained as the difference between the monthly mean forward price and the monthly expected spot price corresponding to the maturity month. Our point is that the dynamics of the premium will depend on the hedging pressures from buyers and sellers of electricity.

As previously commented, the difference in flexibility on the supply and demand side of the electricity market *a priori* leaves the demand side with a higher incentive for hedging in futures contracts. Moreover, since market prices are determined using a uniform-price auction based on marginal price, hedging needs met by producers might not be homogeneous. In fact, units with high variable costs are expected to be exposed to a larger extent to price risk than those of low variable costs, and the former generally produces electricity during times of low hydro capacity.

Therefore, during 'normal market conditions' we would expect the forward premium to be positive. However, expectations of tight market conditions induce the above commented sellers to sell forward contracts in order to reduce variability in their profits. In some circumstances, this downward pressure could be strong enough to generate a negative forward premium. This pressure reflects peak plant generators´ willingness to sell forward contracts to hedge their positions when they envisage that are going to be dispatched.

To measure the expectation of tight market conditions, we employ a variable that takes the value of the expected demand for the maturity month of the forward contract, whenever the level of hydroelectric energy capacity of the current month is lower than its historical mean value (as a proxy of a dry month), and zero, otherwise. We regress the *ex ante* forward premium on this variable and results confirm our intuition, since we obtain a negative relation between the expected demand in tight market conditions and the forward premium (Table 8).

Table 8. Results from regression of ex ante forward premium on expected demand in tight market conditions (March 2006 – February 2007)

$$F_{T,t} - E(S_T) \ = \alpha + \beta_1 \exp\_dem_T(tmc) + \varepsilon_T$$

	α	β_1	R^2
Coefficient	17.261	0.00	40.32%
t-Statistic	32.230	-3.67	

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

As with the *ex post* forward premium, we have tested the implications of the B-L model on the *ex ante* forward premium. According to the B-L model, the forward premium is negatively (positively) related to the spot price variance (skewness). As shown in Table 9, results are partially consistent with the B-L model predictions. The *ex ante* forward premium is negatively related to the spot price variance, as indicated by the value of β and its associated t-statistic. However, we obtain no statistical evidence for the relation between the *ex ante* forward premium and the skewness of spot price.

Finally, the B-L model also predicts that the *ex ante* forward premium should increase with mean demand, due to the positive asymmetry of spot price distribution. It also predicts that, "*ceteris paribus,* forward premium should be convex, initially decreasing, and then increasing in demand risk". To test the previous statement, we estimate the following regression:

$$\overline{F_{T,t} - S_T} = \alpha_0 + \alpha_1 load_T + \alpha_2 DESV(load)_T + \alpha_3 VAR(load)_T + \varepsilon_T \qquad (8)$$

where $F_{T,t}$ denotes monthly mean forward quote in month t for delivery over month T, S_T denotes mean expected spot price for delivery over month T, $load_T$ denotes spot market monthly mean load during month T, and $desv(load)_T$ and $VAR(load)_T$ respectively denote the standard deviation and the variance of the spot market daily load over month T.

Table 9. Regression of ex ante forward premium on the variance and asymmetry of spot prices (March 2006 – February 2007)

$$F_{t,T} - E(S_T) = \alpha + \beta VAR(S_T) + \gamma ASIM(S_T) + \varepsilon_T$$

	α	β	γ	R^2
Coefficient	12.61	-0.19	6.30	44.30%
t-Statistic	*2.64*	*-7.18*	*1.14*	

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

As shown in Table 10, results are consistent with the B-L model predictions as the *ex ante* NM forward premium is positively related to the mean and the variance of load, and negatively related to the standard deviation of load – as indicated by the values of α_1, α_2 and α_3 and their associated t-statistics.

Table 10. Regression of ex ante forward premium on mean demand, standard deviation of demand and variance of demand (March 2006 – February 2007)

$$\overline{F_{T,t} - S_T} = \alpha_0 + \alpha_1 load_T + \alpha_2 DESV(load)_T + \alpha_3 VAR(load)_T + \varepsilon_T$$

	α_0	α_1	α_2	α_3
Coefficient	-47.581820	0.007275	0.000004	-0.026155
t-Statistic	*-1.898*	*4.694*	*3.912*	-3.842368

Note: The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of the variances.

8. CONCLUSIONS

In this work, we focus on the study of the premium embedded in monthly forward prices (concretely, forward contracts for delivery during the next month) in the Spanish electricity market. Some remarkable results emerge from the analysis: (i) We find that the magnitude and the sign of the realized forward premium depend on unexpected variations in demand and on unexpected variations in the level of hydroelectric energy capacity; (ii) We propose a spot price model which enables us to forecast spot price for next month in order to build a series of *ex ante* forward premium. The estimation of this model provides additional interesting insights such as that the statistically positive relationship between Spanish electricity spot prices and the CO_2 emission allowances prices or that the introduction of the new market rules in March 2006 has had no effect on prices; (iii) Once computed the series of *ex ante* forward premium, we obtain the result that it varies with the expected demand during times of small hydro capacity due to the willingness of determined sellers to hedge their price risk; (iv) Finally, we confirm that the implications derived from the B-L theoretical model are supported by the data.

Overall, the achieved results show that the participation of forward dealing agents responds to risk considerations. Finally, we wish to note that the presence of forward premiums in the Spanish market could create incentives to design financial instruments whose yields were indexed to the evolution of electricity prices. These assets could be integrated in the financial portfolios of non-electric investors, and the introduction of speculation into the market may help reduce the magnitude of forward risk premiums.

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