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ELECTRIC POWER INDUSTRY

Master's Thesis

DETERMINANTS OF FORWARD RISK PREMIUM:
AN EMPIRICAL ANALYSIS OF THE SPANISH ELECTRICITY MARKET

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Summary

Motivation

Significant ex-post forward risk premium (the difference between forward and realized spot prices) has been found existing in most of the electricity markets. It is still not clear that if the forward risk premium fully represents compensation to financial market participants for bearing systematic risk, or in fact it contains information not used by market agents which indicates inefficiency in the forward markets. Hence it is very necessary and of significance to study the forward price formation, and further to discover the determinants of the ex-post risk premium associated in forward prices.

Research questions

The main research question is: What are the main determinants of ex-post forward risk premium in the Spanish electricity market?

The sub-research questions are:

- What are the characteristics of ex-post forward risk premium?
- How the risk premium is related to fundamental measures of risks faced by market participates?
- How do supply and demand shocks affect risk assessments and market outcomes?
- What is the effect of regulatory provisions on forward market and forward risk premium?
- What is the effect of speculative and hedging activities on future-spot bias?
- What are the implications for the performance of electricity forward markets?

Theory

The thesis is based on the hedging pressure theory developed by Keynes (1930) that the future contract acts as an instrument for market agents to hedge price risk. The difference between future and expected future prices, namely the ex-ante forward risk premium, is the compensation required by the agent who is willing to bear the spot price risk. Ex-post risk premium as the difference between the future price and the realized spot price at maturity, is an unbiased estimate of the ex-ante risk premium under the assumption that agents form rational forecasts. Bessembinder and Lemmon (2002) develop an equilibrium model for electricity forward prices. Their model implies that the ex-ante forward premium is negatively related to the variance of the spot prices, but positively related to the skewness of spot prices.

Methodology

In this study, future prices for electricity monthly base-load future contracts settled on the last trading day covering delivery time from January 2010 to March 2015 in OMIP, and monthly average spot prices from OMIE were used to calculate the ex-post forward risk premium. We proposed a comprehensive multifactor propositional framework so as to discover the determinants of forward risk premium. It included fundamental influences, behavioral effects, dynamic effects, market hedging, speculative activities and liquidity, regulatory instruments, and shock effects. In addition an econometric model based regression analysis was used to quantify the influence of these determinants on forward risk premium.

Results

Significant positive forward risk premium is found in the Spanish forward markets. The regression results suggest that market agents follow adaptive expectation formation rather than rational expectation. Moreover, the risk premium is positively influenced by regulated auctions, margin shocks, spot price volatility, and negatively influenced by basis.

Conclusion

- The variance of daily spot prices during the trading month positively influences the ex-post risk premium. It indicates that there is more hedging pressure from retailers with risk aversion to spot price volatility. The spot price variance during trading month can be seen as the fundamental risk assessment by market participants who form adaptive price expectation.
- Increasing margin shocks leads to lower realized spot prices, and higher risk premium. Margin shocks represent the misjudgment of future supply and demand conditions by market agents.
- CESUR and OMIP call auctions increased forward prices and forward risk premium during the study period.
- The average positive 10% relative ex-post forward risk premium indicates that future markets results are largely determined by retailers.
- The basis is used as a dynamic estimator of risk premium which captures the links between current spot prices and forward prices, in turn confirming that market agents follow adaptive price formation.
- The residual of the regression model does not confirm normal distribution, implying that there is still information not used by the market agents to form forward prices. Hence market inefficiency cannot be ruled out still.

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1 Introduction

1.1 Background and motivation

The liberalization process in the energy sector, which began in some countries in the early 1990s, has forced the transition from a cost based price regulation towards a market oriented price formation. As a consequence, the wholesale market price is determined by the intersection between demand and supply. Due to the unexpected supply or demand shocks such as unexpected outages of generation units, transmission capacities or weather changes, electricity price presents unique characteristics compared to other commodities with seasonal trend, high volatility and occasional spikes. Moreover, since electricity cannot be stored economically in substantial quantities, price dampening effect of inventories is non-applicable. Hence, market participants have more risk exposure in this new electricity market.

As a result, it encouraged the development of financial markets for electricity to contribute to the market completeness together with physical markets. Future or forward markets play an important role as a mechanism for transferring risks between agents. Electricity producers or consumers could enter a short-term or long-term position in forward markets by setting a fixed price of the underlying at a delivery date. Moreover, forward markets also lead to price discovery since forward price can be used as an indicator of future spot price. Hence it provides signals for investments in the power system, and thereby contributes to a balanced development of supply and demand. Furthermore, the forward market could mitigate market power in the spot market (Allaz & Vila , 1993). Lastly, financial market players also showed increasing interests in electricity forward markets as they provide opportunities for trading and speculation.

The forward and future markets have achieved enormous success with volume traded substantially surpassing the physical demand1. At the same time it also rises the concern about whether the forward markets are operating efficiently, and how to measure the maturity and well-functioning of these markets. Particularly significant ex-post forward risk premium (the difference between forward and realized spot prices) has been found

[1] For example, in Spain the volume traded in forward and future markets in 2014 was 1,62 times the physical demand, see reference http://cnmc.es/Portals/0/Ficheros/Energia/20150115_Informe_seg_mdos_pzo.pdf.

existing in most of the electricity markets. It is still not clear that if the forward risk premium fully represents compensation to financial market participants for bearing systematic risk, or in fact it contains information not used by market agents which indicates inefficiency in the forward markets. Hence it is very necessary and of significance to study the links between forward and spot prices, and further to discover the determinants of the ex-post risk premium associated in forward prices.

Although it has been the main topic of many theoretical and empirical researches, identifying and estimating the components of the risk premium remains a challenging and relatively unsolved area of analysis. One of the most influential findings is the equilibrium model presented by Bessembinder and Lemmon (2002), in which the forward risk premium reflects the risk assessments from market agents assuming rational expectation of spot prices. However, empirical studies for various electricity markets confirmed the implications of the B-L model partially or even found contradictory results (see Haugom and Ullrich (2012), Handika and Trueck (2013) and Redl et al. (2009)). These studies suggest that risk premium cannot be explained by risk considerations only given market agents form rational expectations. In particular, Redl and Burn (2013) take a wider look at the forward price formation, and introduce a multifactor analysis of forward risk premium in the European Energy Exchange (EEX). They find that forward premium in electricity is a rather complex function of fundamental, behavioral, dynamic, market conduct and shock components.

Inspired by those previous works, this thesis aims to develop a more comprehensive analysis of main drivers of forward risk premium in the Spanish electricity market with the most recent data. Besides the rational and behavioral components, it will have a special focus on the hedging, speculative activities, and market liquidity. In addition it will also investigate the performance of the regulatory instruments implemented by the Spanish government in order to foster the forward markets. As a result, this study will bring insights of the functioning and performance of forward markets for the benefits of generators, consumers, financial participants and regulators. These insights enable an efficient and effective design of the markets and its regulatory provisions.

1.2 Objective and contribution

This thesis analyzes electricity future and forward markets. It aims to discover the relationship between future and spot prices, and thereby to gain insights on price and risk divers. Ultimately, it would shed light on the behaviors of market agents and the functioning of forward markets, so as to help regulators better design the rules for a fully liberalized market.

1.2.1 Main research question

The main research question needed to be addressed in this thesis is: **What are the main determinants of ex-post forward risk premium in the Spanish electricity market?**

According to the existing literature, our hypothesis is that ex-post forward risk premium in the Spanish electricity market is determined by fundamental influences, behavioral effects, dynamic effects, market hedging, speculative activities and liquidity, regulatory instruments, and shock effects.

1.2.2 Sub-research questions

By decomposing the main research question, several sub-research questions are generated, respectively:

- What are the characteristics of ex-post forward risk premium?
- How the risk premium is related to fundamental measures of risks faced by market participates?
- How do supply and demand shocks affect risk assessment and market outcomes?
- What is the effect of regulatory provisions on future market and forward risk premium?
- What is the effect of speculative and hedging activities on future-spot bias?
- What are the implications for the performance of electricity forward markets?

1.2.3 Contribution

This paper contributes to the existing literature on the empirical analysis of ex-post forward risk premium by applying in the Spanish electricity market. We developed a multifactor analysis to explain the main determinants of the ex-post forward risk premium. It covers fundamental influences, behavioral effects, dynamic effects, market hedging, speculative activities and liquidity, regulatory instruments, and shock effects. As far as we know, this is the first study using market hedging, speculative activities and liquidity (open interest and volume in forward markets) as determinants of the risk premium. Moreover results also suggest the effects of regulatory instruments implemented by Spanish government on market outcomes.

1.3 Research scope and limitations

This study analyzes the ex-post forward risk premium covering the delivering time from January 2010 to March 2015 in the Spanish electricity market. Specifically, it focuses on the monthly base-load future contracts traded in OMIP with the settlement price on the last trading day before delivery. Hence the time-varying risk premium is not studied in this thesis. Econometric model based linear regression analysis is applied to discover the determinants of the ex-post forward risk premium.

1.4 Structure of the report

The reminder of this thesis is structured as follows: Chapter 2 describes the Spanish spot and forward markets. Chapter 3 provides the theoretical background of risk premium in electricity. In Chapter 4, the data used is detailed together with initial data analysis. Chapter 5 introduces the methodology adopted by this thesis, and develops a propositional framework on the ex-post forward risk premium determinants. Chapter 6 presents the results of the econometric model-based analysis. Finally, Chapter 7 summarizes the results and concludes.

2 The Spanish electricity market

2.1 Spanish wholesale market

The wholesale market in Spain is made up of an organized part and a non-organized part. The organized market is structured around a day-ahead spot market followed by six intraday auctions. The day-ahead spot market is coupled with Portugal since July 2007 and with the NWE region since 13th May 2014. The non-organized part consists of physical bilateral contracts, whose economic terms and conditions are agreed between the signing parties. During 2013 bilateral contracts represented 26% of the sold energy in the daily base-load programme (CNMC, 2014) .

The management of the Iberian spot electricity market is the responsibility of OMEL – Iberian Energy Market Operator – Spanish division, headed in Madrid that began its business in 1998. On the spot electricity market, transactions are executed by the participation of agents on the daily and intraday market that aggregate, through market splitting, the Spanish and Portuguese zones of MIBEL (the Iberian electricity market). Company OMI-POLO ESPAÑOL, S.A.U. (OMIE) manages of the bidding system for the purchase and sale of electricity on the spot market within the sphere of MIBEL.

Trading on the daily market is based on a daily auction, with settlement of energy at every hour of the following day. The price and volume of energy over a specific hour are determined by the point at which the supply and demand curves meet, according to the marginal pricing model .These prices can be different, namely when, for a given hour, the connection is congested, i.e. it is not enough to ensure all the electricity traffic between the two regions. Complementarily, there are various intraday sessions, subsequent to the daily market auction, in which agents can trade electrical energy for the various hours of the day covered by that market. Trading is also done by auction. Spot market prices (day-ahead and intraday) are published at OMIE website (www.omie.es) a few hours after the auctions are finished. Three months later, the bids, transactions and names of the suppliers are published. Therefore, the level of transparency of the spot market is quite high.

2.2 Spanish forward markets

The forward markets in Spain consist of organized future markets managed by OMIP and Over-the-Counter (OTC) markets, in which non-organized OTC remaining dominant. The Spanish OTC market is a non-organized bilateral market, in which traders (usually by means of a broker), trade forward contracts with cash settlement against the arithmetic average of hourly prices in the spot market over the delivery period. Part of the OTC trades are cleared and settled through clearing houses.

OMIP, starting on 3 July 2006, works as Market Operator of the MIBEL Derivatives Market. It ensures the management of the market jointly with OMIClear (The Iberian Energy Clearing House), a company constituted and totally owned by OMIP. OMIP provides base-load and peak-load futures contracts with weekly, monthly, quarterly and yearly maturity periods. There are two trading modes coexisting within OMIP: the continuous market (default mode) and the call auction. In the continuous trading, anonymous buy and sell orders interact immediately and individually with opposite side orders, generating trades with an undetermined number of prices for each contract. Buy orders with the highest prices and sell orders with the lowest prices are executed first. In the call auction trading, a single-price auction maximizes the traded volume, being all trades settled at the same price (equilibrium price). The call auction algorithm is based on the maximum tradable volume and minimum price criteria, following a First In First Out allocation method. The OMIP call auctions has performed a key role in the development of the liquidity in OMIP, as the Spanish distribution companies and the Portuguese last resort supplier were obliged to purchase regulatory fixed volumes energy in such auctions (Capitan Herraiz & Rodriguez Monroy, 2013). The last OMIP call auction for the Spanish base-load forward contracts was held on September 14, 2010 for delivery period of Q4 in 2010. Auction results are available on the OMIP website. They consist of monthly, quarterly and yearly forward contracts.

Additionally, OMIClear executes the role of Clearing House and Central Counterparty of operations carried out on the market. OMIP trading members may settle Over the Counter (OTC) trades through OMIClear, either registrating their transactions by themselves or through a broker. Moreover, bilaterally traded OTC for the Spanish forward may be also registered through the Clearing House BME Clearing or through European Commodity Clearing AG (ECC).

2.3 CESUR auctions

Similar to the same functioning of OMIP call auctions, CESUR (Contracts of Energy for the Last Resort Supply) auctions were a compulsory purchase mechanism for the last resort suppliers in the Spanish market. The auction prices were used as the estimated forward energy cost in the price formula for the last resort tariff. The products purchased by the last resort suppliers in the CESUR auctions were standard forward contracts (base load and peak products) also traded in the forward markets. In this sense, there is a strong interrelation between the resulting equilibrium price in these auctions and the price formation in the existing organized and non-organized markets (OMIP and OTC markets).

CESUR auctions were managed by OMEL Mercados (one of OMIE's subsidiary companies). The results as quarterly forward contracts were published on its website (http://www.omelmercados.es). The last 25th CESUR auction, to be delivered at the first quarter of 2014, took place on December 19, 2013. However CNMC did not validate the results of 25th CESUR auction, given the atypical circumstances in which the auction was held (CNMC, 2014). As a remedy for the absence of valid reference prices for such an ex-ante calculation (CESUR auction), the Royal Decree 216/2014 sets out the method for calculating voluntary prices for the small consumer of electrical energy, changes from fixing in advance the energy cost component through the CESUR auctions, into a mechanism in which the consumer will pay for the energy consumed in the invoicing period valued at the spot price in such a period.

2.4 Generation mix

In this section a brief description of the electricity generation mix in Spain (mainland) is presented. Table 2.1 and Table 2.2 list installed power capacity until December 31, 2014 and the energy balance by energy technologies in 2014 in Spain (mainland).

Up to 31st December 2014, the installed power capacity in Spain amounted to 102,262 MW, in which 62,497 MW belonging to conventional technologies (61.1% of total installed capacity), 39,765MW belonging to renewable technologies (38.9% of total installed capacity), see Table 2.1. In particular, the installed capacity of CCGT plants was the highest in the Spanish generation park, amounting to 25,348 MW and constituted almost one quarter the total installed capacity. It is followed by: wind power turbines (22,845 MWh, 22.3%); hydro power stations run by conventional operators (17,791 MWh, 17.4%); and coal-fired thermal power plants (10,972 MWh, 10.7%).

In terms of generated power, as shown in Table 2.2, the largest electricity generation is from nuclear (57.4 TWh), followed by wind (50.6 TWh) and coal (44.1TWh). Whilst the CCGT plants produced in total 22 TWh representing merely 8.7 % of the net generation in mainland Spain, 2014. This is caused due to the combined effect of lower electricity demand and a higher output from renewables. In 2014, total renewables produced 94TWh, amounting to 37.2% of the net generation, in which wind itself contributed 20%.

From Table 2.1 and Table 2.2, it can be seen that although CCGT plants still contain the largest installed capacity in Spain, its impact on the power system is decreasing due to the substantial reduction of electricity production. At the same time renewable energies especially the wind technologies started to play an important role in the overall generation mix.

Installed Capacity (31 December, 2014) in Spain (mainland)		
	MW	%Total
Hydro	17,791	17.4%
Nuclear	7,866	7.7%
Coal	10,972	10.7%
Fuel/Gas	520	0.5%
Combined Cycle	25,348	24.8%
Conventional Total	62,497	61.1%
Hydro rest	2,105	2.1%
Wind	22,845	22.3%
Solar PV	4,428	4.3%
Solar Thermal	2,300	2.2%
Thermal Renewables	1,012	1.0%
Cogeneration and rest	7,075	7.0%
Renewables Total	39,765	38.9%
Total	102,262	100%

Table 2.1 Installed capacity in Spain (mainland) until December 31, 2014. Source: REE[2]

[2] http://www.ree.es/sites/default/files/downloadable/inf_sis_elec_ree_2014.pdf

Energy Balance in Spain (mainland) of Year 2014		
	GWh	% Net Generation
Hydro	35,860	14.1%
Nuclear	57,376	22.6%
Coal	44,064	17.4%
Fuel/Gas	0	0%
Combined Cycle	22,060	8.7%
Total Conventional Generation	159,360	62.8%
Consumption for Power Generation	-6,561	-2.6%
Hydro rest	7,067	2.8%
Wind	50,630	20.0%
Solar PV	7,794	3.1%
Solar Thermal	4,959	2.0%
Thermal Renewables	4,718	1.9%
Cogeneration and rest	25,596	10.1%
Renewables Total	94,203	37.2%
Net Generation	253,564	100%
Pumped storage consumption	-5,330	
Península-Baleares Link	-1,298	
International exchanges	-3,406	
Total Demand	243,530	

Table 2.2 Electricity production per technology in Spain (mainland) in 2014. Source: REE

3 State of the art

This section will describe the main theories about the relationships between commodity spot and futures prices, namely the cost-carry theory and the hedging pressure theory. Afterwards more details about the forward risk premium will be discussed. Lastly empirical findings are presented so as to give a better perception of the risk premium in electricity markets.

3.1 Two theories of forward contracts pricing

There are mainly two theories in terms of price formation of future contracts. The first one, "cost-of-carry" theory, is closely linked to the cost and convenience of holding inventories under non-arbitrage condition. The second is the "hedging pressure" theory, which applies a risk premium to derive a model for the relationship between spot and future prices. Both theories are briefly reviewed below, followed by a discussion about their relevance in the electricity market.

3.1.1 Cost-of-carry theory

The cost-of carry theory dating back to Kaldor (1939), explains the difference between current spot prices and futures prices for future delivery in terms of interest foregone in storing a commodity, storage cost, and a convenience yield on inventory. Hence the future contracts cam be priced under non-arbitrage condition using the following formula:

$$F_{t,T} = S_t e^{(r+c-y)(T-t)}$$

Equation 3.1

In which $F_{t,T}$ is the future price at time t for delivery at time T, S_t is the spot price at time t, r is the risk free interest rate, c is the cost of storage, y is the convenience yield. Specifically, the convenience yield is defined as the benefit from owning the physical commodity that is not obtained by holding a futures contract. It can be regarded as a liquidity premium and represents the privilege of holding a unit of inventory, for instance to be able to meet unexpected demand or to keep an operation running.

It is important to notice that the no-arbitrage argument underlying this model relies on the ability of arbitrage to take a position in the underlying asset and hold it until the contract expiration date. However, it cannot be directly applied to electricity future prices due to the fact that electricity is essentially non-storable.

3.1.2 Hedging pressure theory

The alternative is the "hedging pressure" theory developed by Keynes (1930), which can be employed when the underlying commodity is both non-storable and storable. This theory is the most popular approach for studying the relationship between spot and future prices in power markets due to the non-storability of electricity. Based on this approach, the future contract acts as an instrument for market agents to hedge price risk. Particularly, this literature has traditionally focused on what is termed the ex-ante forward risk premium. It is defined by Fama and French (1987) as the difference between the future prices and the expected spot price as follows:

$$F_{t,T} = E_t(S_T) + RP_{ex-ante\ t,T}$$

Equation 3.2

Where $F_{t,T}$ is the future price at time t for delivery at time T, $E(S_T)$ is the expected spot price at time t, $RP_{ex-ante\ t,T}$ is the ex-ante forward risk premium. Expected spot prices reflect market agents' expectations of fundamental supply and demand conditions during the delivery period of the future contract. The difference between future and expected future prices, namely the ex-ante forward risk premium, is the compensation required by the agent who is willing to bear the spot price risk ((Bessembinder & Lemmon, 2002) and (Longstaff & Wang, 2004)).

3.2 The forward risk premium: ex-ante & ex-post

Since the ex-ante forward risk premium in (3.2) relies on the expected spot price, which is not directly observable in the market. It requires to model the stochastic dynamics of the spot prices. The main disadvantage of this approach lies in obtaining reliable estimate of spot prices since different models will generate different spot price expectations, and thereby difference values of risk premium (Lucia & Torró, 2011).

As an alternative, ex-post risk premium is computed to avoid the difficulties associated with expected spot prices. It is defined as the difference between the future price and the realized spot price at maturity, hence no direct assumption of the spot price is needed. The formula is shown in (3.3).

$$F_{t,T} = S_T + RP_{ex-post\ t,T}$$

Equation 3.3

Where $F_{t,T}$ is the future price at time t for delivery at time T, S_T is the realized spot price at time t, $RP_{ex-post\ t,T}$ is the ex-post forward risk premium. The link between ex-ante risk premium and ex-post risk premium can be obtained by substituting the expression for $F_{t,T}$ from (3.2) in (3.3). Thus,

$$RP_{ex-post\ t,T} = RP_{ex-ante\ t,T} + E_t(S_T) - S_T$$

Equation 3.4

In other words, the ex-post forward risk premium can be interpreted as the sum of (a) the ex-ante forward risk premium, and (b) the predicted errors for the expected spot price at time t. Hence ex-post forward risk premium is an unbiased estimate of the ex-ante risk premium under the assumption that agents form rational forecasts, implying that predicted errors are not correlated with the available information at time t. In this thesis, ex-post forward risk premium is adopted for analysis.

3.3 Empirical findings on forward risk premium

Many empirical studies have proved the existence of risk premium in difference electricity markets worldwide. Gjolberg and Johnsen (2001) and Botterud et al. (2002) identify positive risk premiums in the Nordic market. Gjolberg and Johnsen (2001) argue that due to the identified size, differences cannot be explained by risk premiums only but would indicate informational inefficiencies or the exercise of market power because of the high concentration of suppliers. Bunn (2006) identifies positive risk premiums for peak hours when comparing the UK day ahead and prompt market and the week ahead and day ahead market. He argues, that during peak hours the demand side has a higher willingness to pay day ahead in order to avoid high volatility in the intra-day market. Cartea and Villaplana (2008) study the forward premia dynamics of England and Wales during the period 1999-2006, NordPool during 2000-2006, and PJM during 1999-2006. The authors find that in all markets the forward premium is seasonal and there are months where it is positive and others when it is negative. Furió and Meneu (2010) analyze the forward premium in the Spanish market during the period 2003 to 2008. They find that the ex-post premium using monthly contracts is not statistically significant different from zero although there is considerable variation from month to month.

As one of the most influencing works on risk premium in electricity markets, Bessembinder and Lemmon (2002) develop an equilibrium model for electricity forward prices based on the assumptions that both the supply and demand sides are risk averse and price is settled by producers and retailers excluding speculators outside the industry. Their model implies that the forward price will be a biased forecast of the spot price. Furthermore, the ex-ante forward premium is negatively related to the variance of the spot prices, but positively related to the skewness of spot prices. However this model has been under scrutiny by applying in different markets. Using PJM real-time (called ‘spot’) and day-ahead (‘forward’) data, Longstaff and Wang (2004) generally confirm the findings of the Bessembiner–Lemon (B–L) model. Diko et al.(2006) come to similar conclusions using European data.

Other works, on the other hand, confirm the implications of the B–L model only partially or do not confirm them at all. Haugom and Ullrich (2012) repeat the study of Longstaff and Wang (2004) for a longer dataset (2001–2010) in PJM market. They analyze the stability of the parameters of variance and skewness in the risk premium regression. Their conclusion is that the parameters vary significantly and that the results are not consistent with the B–L model. Handika and Trueck (2013) do not confirm the B–L model for Australian data, with coefficients being often insignificant or of other sign than expected. Redl et al. (2009), who analyze EEX and Nord Pool data give very weak support of the B–L model obtaining, as expected, a positive skewness coefficient for EEX, but insignificant coefficients of mixed signs in all other cases. Furió and Meneu (2010) confirmed that the implications derived from the B-L model are partially supported by the Spanish data.

The possible explanations about why empirical studies did not support the B-L model could be that the model may omit important elements of the system by not considering speculative activities, or because of the oversimplification of the price formation. As indicated in Douglas and Popova (2008) and Redl and Bunn (2013), market agents follow adaptive expectation formation instead of rational expectations, thus they forecast spot prices based on the current spot prices. In addition, Redl and Bunn (2013) test the ex-post risk premium in the European Energy Exchange (EEX) with a wide-ranging set of variables. They conclude that risk premium is a complex function of fundamental, behavioral, market structure, dynamic and external shock components. Moreover, as emphasized by Huisman and Kilic (2012), the risk premium may behave differently depending on the characteristics of the market. Hence it is noteworthy to perform additional studies on Spanish electricity market with the most recent data, due to the fact that it has not been investigated thoroughly. By conducting a comprehensive analysis of the risk premium in Spanish electricity market, it would bring new and more informative insights into the functioning of Spanish forward markets, and price formation of electricity forward markets in general.

4 Data sources and initial data analysis

4.1 Data sources

The data sample for this study is a combination of different datasets. The primary data consists of hourly electricity base-load spot prices from OMIE wholesale market and daily settlement prices of electricity base-load one-month-ahead future contracts from OMIP future market. In addition, data of renewable energy generation and electricity demand in Spain, oil prices, natural gas spot and future prices, open interest and trading volume in OMIP market, OMIP call auctions and CESUR auctions will also be used for the analysis. Furthermore, each dataset is described in detail as follows.

4.1.1 Electricity future and spot prices data

As risk premium in electricity market is defined as the difference between future and spot prices, these two datasets consist the primary data in this study.

Electricity future prices

The dataset of electricity future prices in Spain is obtained directly from the website of The Iberian Energy Derivatives Exchange OMIP (http://www.omip.pt). In this study we focus on month-ahead base-load future contracts. Future prices cover the trading period from December 1, 2009 to February 28, 2015, amounting 1,916 daily observations for all monthly futures with the maturity period from January 2010 to March 2015. More specifically, we consider only prices on the last trading day before the delivery month. For instance, the last trading day for monthly future base-load contract to be delivered during 24h of everyday in January 2010 is December 29, 2009. Hence the future price observed on December 29, 2009 is chosen as the final settlement price for monthly future contract delivered during January, 2010.

Redl and Bunn (2013) mentioned several reasons for choosing month-ahead futures instead of other types of futures. Firstly, this is the most liquid contract and most price data is available for futures with monthly delivery periods. Secondly, due to the near-term delivery period, the forecast errors of market participants should, on average, be low for up to one month ahead. Lastly prices on the last trading day before the delivery month are considered due to the limited availability of fundamental data. Besides, this is also the less speculative reference since if a participant buys(sells) a monthly contract on the last trading day he cannot sell (buy)this contract any more. Hence in total there are 63 month-ahead base-load future settlement prices delivered from January 1, 2010 to March 1, 2015. Prices are expressed in Euro/MWh.

Electricity spot prices

The dataset of electricity spot prices in Spanish wholesale market is obtained directly from the website of Spanish Market Operator OMIE (http://www.omie.es). Spot prices cover the period from December 1, 2009 to March 31, 2015, amounting 46,728 hourly spot price observations. In this study only daily electricity base-load price index will be investigated. It is computed as the arithmetic mean of the day-ahead hourly prices over the 24 hours of the day, in total 1,947 daily average spot price observations. Moreover, in line with the monthly future contract, monthly average of daily spot prices was obtained in order to calculate the forward risk premium. Hence there are 64 monthly average base-load spot price observations from December 2009 to March 2015. Prices are expressed in Euro/MWh.

4.1.2 Electricity supply and demand data

Electricity supply and demand play fundamental roles in terms of influencing spot and future prices. The daily statistics of the Spanish peninsular electricity system are provided by Spanish transmission system operator Red Eléctrica de España (REE). Monthly report can be downloaded from its website (http://www.ree.es/en/activities/daily-balancing). This report provides detailed data of daily electricity generation and demand in each month.

Renewable energy generation

In this study, we consider the daily renewable energy generation among the whole generation in Spanish electricity system for time period from December 1, 2009 to March 31, 2015, amounting 1,947 daily observations. Before January 1, 2014, REE used the category "**Special Regime**" to represent all the intermittent energy sources. Since January 1, 2014, REE provided a detailed breakdown of the generation obtained from this special Regime, including hydroelectric, wind, solar photovoltaic, solar thermal, renewable thermal and non-renewable thermal. Because we are only interested in the data of monthly frequency, the monthly average of renewable energy generation is calculated, amounting 64 data samples covering time period from December 2009 to March 2015. The official data given by REE is presented in megawatt hour (MWh), we present in megawatt (MW) by dividing the number of hours.

Electricity demand

Similar to the renewable energy generation, daily electricity demand data can also be retrieved from the REE website. Primary data for electricity demand in Spain covers time period from December 1, 2009 to March 31, 2015, amounting 1,947 daily observations. To be consistent, we use the monthly average electricity demand, amounting 64 data samples from December 2009 to March 2015. Data is presented in megawatt (MW).

4.1.3 Other data

Natural gas future and spot prices

Since there is no natural gas marketplace inside Spain, we choose two trading points on the European continent. One is the National Balancing Point, commonly referred to as the **NBP**, is a virtual trading location for UK natural gas. It is the pricing and delivery point for the **ICE Futures Europe** (Intercontinental Exchange) natural gas futures contract. It is the most liquid gas trading point in Europe (National Balancing Point (UK), 2015). Prices at NBP trades are initially published in GBp/Therm. They are converted to Euro/MWh based on the exchange rate published on the website of European Central Bank (http://www.ecb.europa.eu).

The other trading point is the Title Transfer Facility, more commonly known as **TTF**, is a virtual trading point for natural gas in the Netherlands. It is almost identical to the National Balancing Point (NBP) in the UK. Physical short-term gas and gas futures contracts are traded and handled by the **ICE-Endex Exchange**. Gas at TTF trades in Euro/MWh (Title Transfer Facility, 2015). Spot market of NBP gas and TTF gas are mostly taken place OTC.

All the data about natural gas futures and spot prices is obtained from Bloomberg available in CNMC. To be consistent with electricity futures, we focus on month-ahead natural gas futures with the settlement price on the last trading day. NBP ICE future prices and TTF ICE-Endex future prices cover the trading period from November 1, 2009 to January 31, 2015, amounting 1,918 daily observations for all monthly futures with the maturity period from December 2009 to February 2015. We obtained 63 month-ahead natural gas future prices observations on the last trading day for NBP gas and TTF gas delivered from December 1, 2009 to February 1, 2015. The primary daily spot prices for NBP gas OTC and TTF gas OTC cover time period from December 1, 2009 to February 28, 2015, in total 1916 daily closing prices. Furthermore, 63 monthly average spot prices for NBP gas OTC and TTF gas OTC are calculated covering from December 2009 to February 2015. All prices are expressed in Euro/MWh.

Crude oil prices

Brent is a benchmark assessment of the price of physical, light North Sea crude oil. It is used to price two thirds of the world's internationally traded crude oil supplies. The daily Brent oil spot prices are available from Platts, covering time period from December 1, 2009 to February 28, 2015, amounting 1,916 daily observations. 63 monthly average Brent spot prices are obtained for period from December 2009 to February 2015. The Brent prices are obtained from Bloomberg available in CNMC. The initial data presented in US$/Bbl, is converted to Euro/Bbl based on the exchange rate published on the website of European Central Bank.

CESUR and OMIP call auctions

CESUR (Contracts of Energy for the Last Resort Supply) and OMIP call auctions were a compulsory purchase mechanism for the last resort suppliers in the Spanish market. The auction prices were used as the estimated forward energy cost in the price formula for the last resort tariff. The products purchased by the last resort suppliers in the CESUR and OMIP auctions were standard forward contracts (base load and peak products) also traded in the forward markets.

CESUR auctions were managed by OMEL Mercados (one of OMIE's subsidiary companies). The results as quarterly forward contracts were published on its website (http://www.omelmercados.es). The last 25th CESUR auction, to be delivered at the first quarter of 2014, took place on December 19, 2013. However CNMC did not validate the results of 25th CESUR auction, given the atypical circumstances in which the auction was held (CNMC, 2014). In this study we still consider this auction with reasons explained in the following section. Hence in total we have 16 base-load observations from the 10^{th} until the 25^{th} auction. They cover 51 delivery months from January 2010 to March 2014. Results are expressed in MW.

The OMIP call auctions were aimed to facilitate the development of liquidity in Spanish forward markets transitorily. The last OMIP call auction for Spanish base-load forward contracts was held on September 14, 2010 for delivery period of Q4 in 2010. Auction results are available on the OMIP website. They consist of monthly, quarterly and yearly forward contracts. In this study, we consider all these three types of forward contracts auctioned in OMIP in order to analyze their overall impact on forward market liquidity. For delivery period from January 1, 2010 to December 1, 2010, we have collected in total 67 OMIP call auctions covering trading days discretely from January 7, 2009 to September 14, 2010. More specifically, for each delivery month, the OMIP call auction quantity is computed as the sum of monthly, quarterly and yearly forward contracts covering that month. Hence we have 12 monthly base-load OMIP call auction observations for delivery period from January 2010 to December 2010. Results are expressed in MW.

Open interest in OMIClear and trading volume in organized and non-organized markets (OMIP and OTC markets)

Open interest and trading volume can be used as the measurements of speculative and hedging activities in the Spanish electricity future market. Open interest data is available on the OMIP website. Volume data is from OMIP and brokers.

The volume consists the trades in OMIP continuous market, OMIP call auctions and OTC registered in OMIP for clearing and settlement by OMIP clearing house (OMIClear) and OTC traded with the intermediation of brokers and non-registered through OMIClear.. For base-load contracts with delivery period from January 1, 2010 to March 1, 2015, we have collected in total 50,347 daily trading volume covering trading days from July 15, 2008 to February 27, 2015. More specifically, for each delivery month, the trading volume is computed as the sum of monthly, quarterly and yearly forward contracts covering that month. Hence we have 63 monthly base-load trading volume observations for delivery period from January 2010 to March 2015. Results are expressed in MW.

Open interest equals the number of outstanding long positions (or equivalently, short positions) at the end of the day. It reflects the trading behavior, as it shows the net positions of OMIP trading members, i.e. the amount of futures contracts that may be used for hedging against the volatility and uncertainty of the underlying spot price. On the last trading day of month-head forward contracts, the open interest includes number of outstanding contracts (sum of monthly, quarterly and yearly forward contracts) covering delivery period of that month. For instance, December 29, 2009 was the last trading day of monthly forward contract delivered from January 1, 2010. Hence the open interest on December 29, 2009 includes monthly contract delivered in January 2010, quarterly contract delivered in first quarter of 2010 and yearly contract delivered in 2010. Open interest is published on OMIP's website on each trading day. It took OMIP continuous market, OMIP call auctions and OTC registered in OMIP into account. For monthly base-load forward contracts with delivery period from January 1, 2010 to March 1, 2015, we have collected in total 1,916 daily observations covering the trading days from December 1, 2009 to February 28, 2015. Since we focus on the last trading day, we have 63 open interest observations for monthly base-load forward contracts with delivery period from January 2010 to March 2015. Results are expressed in MW.

The trading volume simply accounts for the amount of trading activity that has taken place of monthly, quarterly and yearly forward contracts until the last trading date. On the contrary, the daily open interest figure determines the number of outstanding contracts at the last trading day; i.e. the number of contracts that have been entered into but not yet liquidated (see (Lucia & Pardo, 2010)).

4.1.4 Summary of data

Table 4.1 below lists the summary of data that we have collected and will be used for analysis during the next step in this study. Noticeably, they have been modified into monthly frequency from the most original datasets. More information about the description of each dataset, counts of observations, time period of datasets, sources and units are given in the table.

Data	Description	Counts	Time period		Sources	Units
			From	To		
Electricity future prices	Last trading day settlement prices of month-ahead base-load future contract	63	Delivered Jan. 1, 2010	Delivered Mar. 1, 2015	OMIP	Euro/MWh
Electricity spot prices	Monthly average of daily base-load spot prices (daily price is the average of 24 hourly spot prices)	64	Delivered Dec. 1, 2009	Delivered Mar. 1, 2015	OMIE	Euro/MWh
Renewable energy generation	Monthly average of daily renewable energy generation (special regime)	64	Dec. 1, 2009	Mar. 1, 2015	REE	MW
Electricity demand	Monthly average of daily electricity demand	64	Dec. 1, 2009	Mar. 1, 2015	REE	MW
Natural gas future prices	Last trading day settlement prices of month-ahead natural gas future contract	63*2	Delivered Dec. 1, 2009	Delivered Feb. 1, 2015	NBP ICE TTF ICE-Endex	Euro/MWh
Natural gas spot prices	Monthly average of daily natural gas spot prices	63*2	Delivered Dec. 1, 2009	Delivered Feb. 1, 2015	NBP OTC TTF OTC	Euro/MWh
Crude oil spot prices	Monthly average of daily Brent oil spot prices	63	Delivered Dec. 1, 2009	Delivered Feb. 1, 2015	Platts	Euro/Bbl
CESUR auction	Quantity of CESUR auction for monthly base-load forward contracts	51	Delivered Jan. 1, 2010	Delivered Mar. 1, 2014	OMEL Mercados	MW
OMIP Call auction	Quantity of OMIP auction for monthly base-load forward contracts (sum of monthly, quarterly and yearly for each month)	12	Delivered Jan. 1, 2010	Delivered Dec. 1, 2010	OMIP	MW
Trading volume	Volume of monthly base-load forward contracts traded in OMIP continuous, OMIP call auctions, OTC registered in OMICear and OTC non-registered (sum of monthly, quarterly and yearly for each month)	63	Delivered Jan. 1, 2010	Delivered Mar. 1, 2015	OMIP Brokers	MW
Open interest	Open interest on the last trading day of month-ahead base-load future contract	63	Delivered Jan. 1, 2010	Delivered Mar. 1, 2015	OMIP	MW

Table 4.1 Summary of data processed in monthly frequency

4.2 Initial data analysis

<u>Electricity spot and future prices</u>

The time series of monthly-average electricity spot base-load prices as well as month-ahead electricity base-load future settlement prices on the last trading day for the maturity period from January 2010 to March 2015 is plotted in Figure 4.1. Table 4.2 shows the main summary statistics indicators of them.

As shown in Figure 4.1, Spot prices were rising continuously until later 2011, and starting to decrease after that. Practically there were two moments of extreme drops of spot prices below than 20 Euro/MWh, one was in April 2013 and the other was in February 2014. Future prices showed the similar movement as spot prices, which can be confirmed from the statistics given in Table 4.2. The average future prices 46.40 Euro/MWh is comparable in magnitude to the average spot prices 44.14 Euro/MWh. They both have similar values of skewness and kurtosis. On the other hand, however, there are some key differences between the electricity spot and future prices. Specifically, the standard deviation of future prices is lower than the spot prices, implying that future prices tend to be less volatile than spot prices, which can be clearly observed from the Figure 4.1. Furthermore, future prices do not display as much extreme variation as spot prices. In particular, the maximum future price is lower than the maximum spot price, and the minimum future price is higher than the minimum spot price. Lastly, different as the results in the work of Redl and Bunn (2013), Spanish monthly average spot prices showed negative skewness, implying that there are more extreme low spot prices compared to German electricity market.

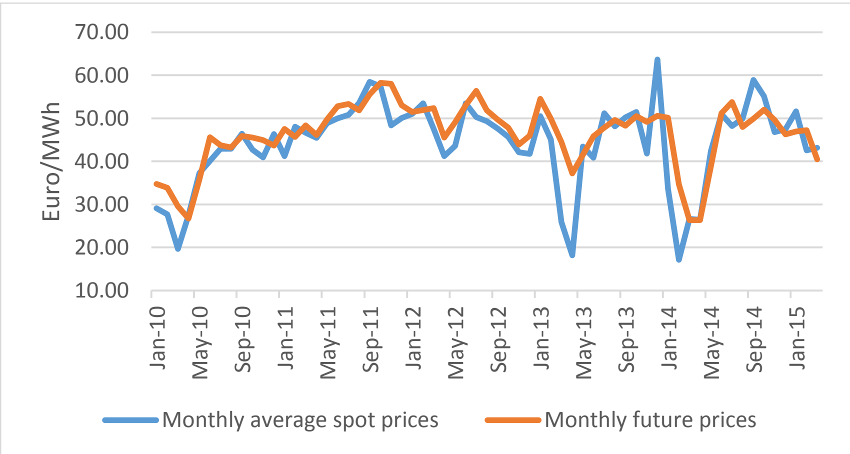


Figure 4.1 Evolution of monthly average base-load spot prices and base-load month-ahead futures prices on the last trading day from January 2010 to March 2015. Source: OMIE & OIMP-OMIClear.

	Base-load month-ahead futures prices on the last trading day	Monthly average base-load spot prices
Mean	44.14	46.40
Median	46.44	47.85
Maximum	63.64	58.25
Minimum	17.12	26.30
Standard deviation	9.86	7.37
Coefficient of variation	0.22	0.16
Skewness	-1.01	-1.14
Kurtosis	3.81	4.00

Prices are quoted in Euro/MWh

Table 4.2 Descriptive statistics of monthly average base-load spot prices and base-load month-ahead futures prices on the last trading day from January 2010 to March 2015. Sources: OMIE & OMIP-OMIClear

Renewable energy generation and electricity demand

Figure 4.2 depicts the evolution of monthly average renewable energy generation and electricity demand in Spain. Renewable energy generation has been growing continually during the past five years, as can be seen from the Figure 4.2, while demand keeps relatively stable. Table 4.2 gives descriptive statistics of monthly average renewable generation, monthly average relative renewable generation (defined as the ratio between renewable generation and demand) and electricity demand. Although the standard deviations for renewable generation and demand are very similar, the coefficient of variation [3] of renewable generation is much higher than demand, implying that renewable energy generation is very volatile. Besides, the similar positive skewness coefficient, with positive kurtosis, indicate that, there are both possibilities of extreme high renewable energy generation and electricity demand.

[3] Coefficient of variation is defined as the ratio between standard deviation and mean.

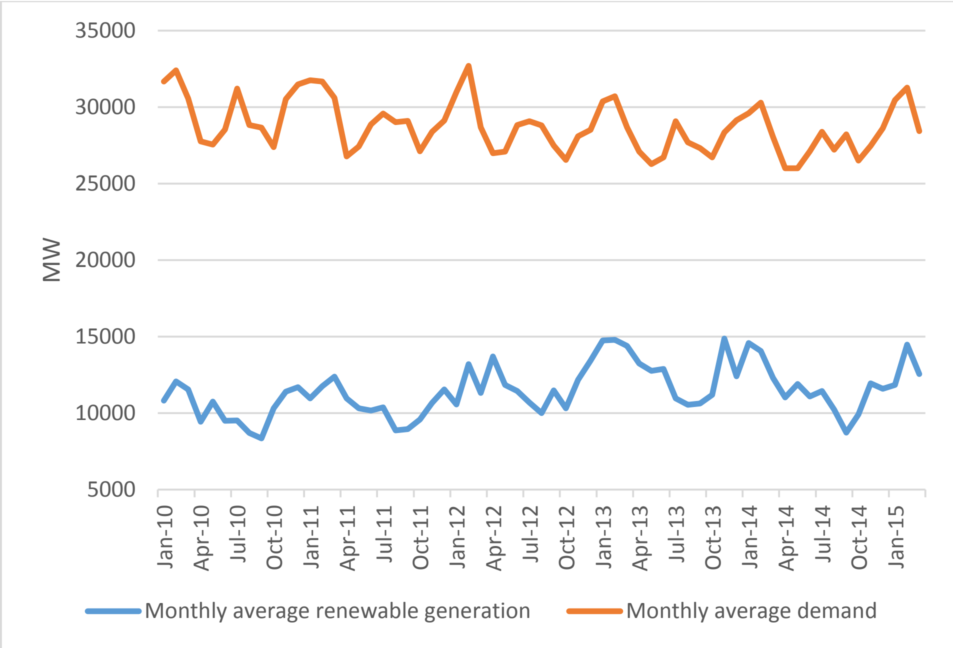


Figure 4.2 The evolution of monthly average renewable energy generation and electricity demand in Spain from January 2010 to March 2015. Source: REE.

	Renewable energy generation	Electricity demand	Relative renewable energy generation*
Mean	11456	28756	0.401
Median	11391	28621	0.391
Maximum	14867	32698	0.526
Minimum	8352	25994	0.295
Standard deviation	1624.0	1693.4	0.056
Coefficient of variation	0.142	0.059	0.141
Skewness	0.369	0.470	0.221
Kurtosis	2.64	2.38	2.39

-Generation and demand are quoted in MW.

*Relative renewable energy generation is defined as the ratio between renewable generation and demand.

Table 4.3 Descriptive statistics monthly average renewable energy generation, relative renewable energy generation and electricity demand in Spain from January 2010 to March 2015. Source: REE

As mentioned before, electricity spot prices are determined fundamentally by the supply and demand. Figure 4.3 presents the time series of monthly average electricity spot prices and monthly average relative renewable generation. It clearly shows the negative relation between spot prices and renewable energy generation. Hence it can to a large extent explain the two extreme low realizations of spot prices, respectively in April 2013 and in February 2014, when renewable energy generations were quite high.

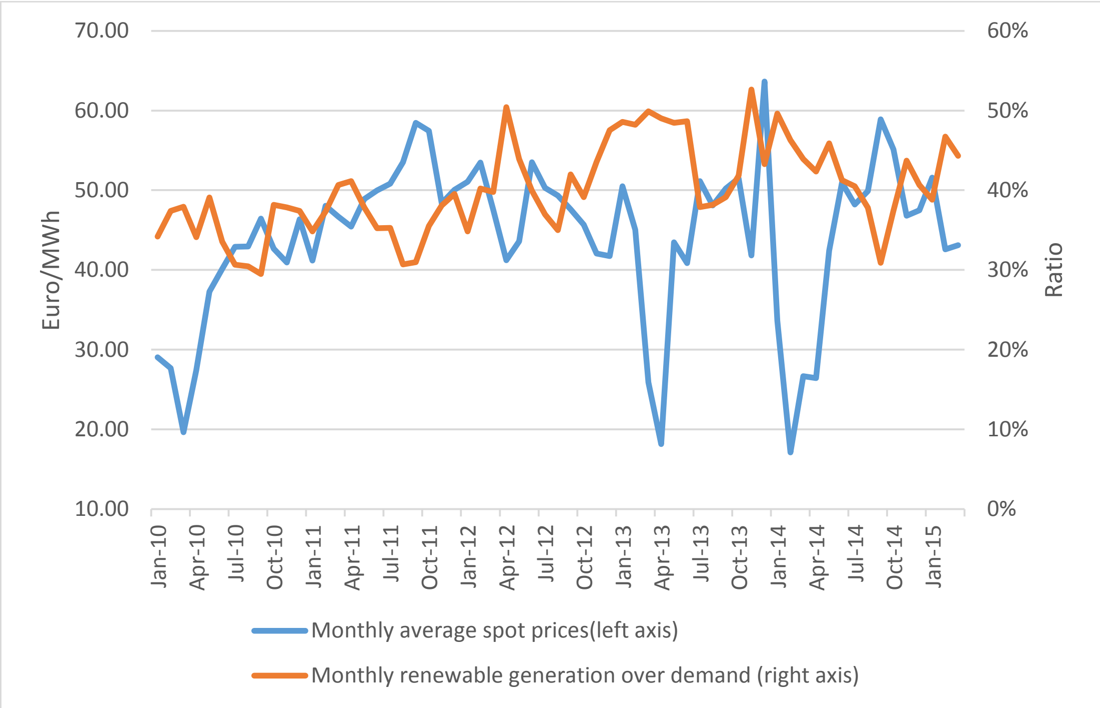


Figure 4.3 The evolution of monthly average electricity spot prices and monthly average relative renewable generation in Spain from January 2010 to March 2015. Source: OMIE & REE.

The electricity demand exhibits clear seasonal trend with peak values in February and off-peaks in April and May as shown in Figure 4.2. Here we take a simple regression test based on STATA to check for seasonal trends in electricity demand using four seasonal dummies, respectively representing Q1, Q2, Q3 and Q4. The following regression is estimated:

$$Demand_t = b1Q1_t + b2Q2_t + b3Q3_t + b4Q4_t + \varepsilon_t$$

Equation 4.1

Where b is the regression coefficients and Q is the dummy for the respective quarter. The result of the regression analysis is summarized in Table 4.4. We can see that four quarters all proved to have significant regression coefficients at 5% level, in which Q1 has the largest demand and Q2 has the smallest demand (see Appendix A).

Panel A	**cons**	**b1**	**b3**	**b4**	**N**
Coefficient	27268.6*	3226.0*	1378.1*	998.1**	63
t-statistic	114.69	8.05	3.59	2.28	
Panel B	Adj.R^2	AIC	BIC	D-W	
	0.51	1077.081	1085.654	1.26	

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1 %(5%, 10%) level.

$$Demand_t = \text{cons} + b1Q1_t + b3Q3_t + b4Q4_t + \varepsilon_t$$

Table 4.4 Results of regression analysis (4.1) for electricity demand on seasonal dummies from January 2010 to March 2015. Sources: REE

Natural gas spot and future prices

The time series of monthly average natural gas spot prices as well as month-ahead natural gas future prices observed on the last trading day for NBP and TTF covering the maturity period from December 2009 to February 2015 is plotted in Figure 4.4. Table 4.5 shows the main summary statistics indicators of them.

As shown in Figure 4.4, monthly average spot prices of NBP gas and TTF gas are almost the same, the same as month-ahead future prices of NBP gas and TTF gas. Moreover there is little difference between natural gas spot and future prices, which is very different from the case of electricity spot and future prices. This is also confirmed in Table 4.5 that all values in four columns are very close.

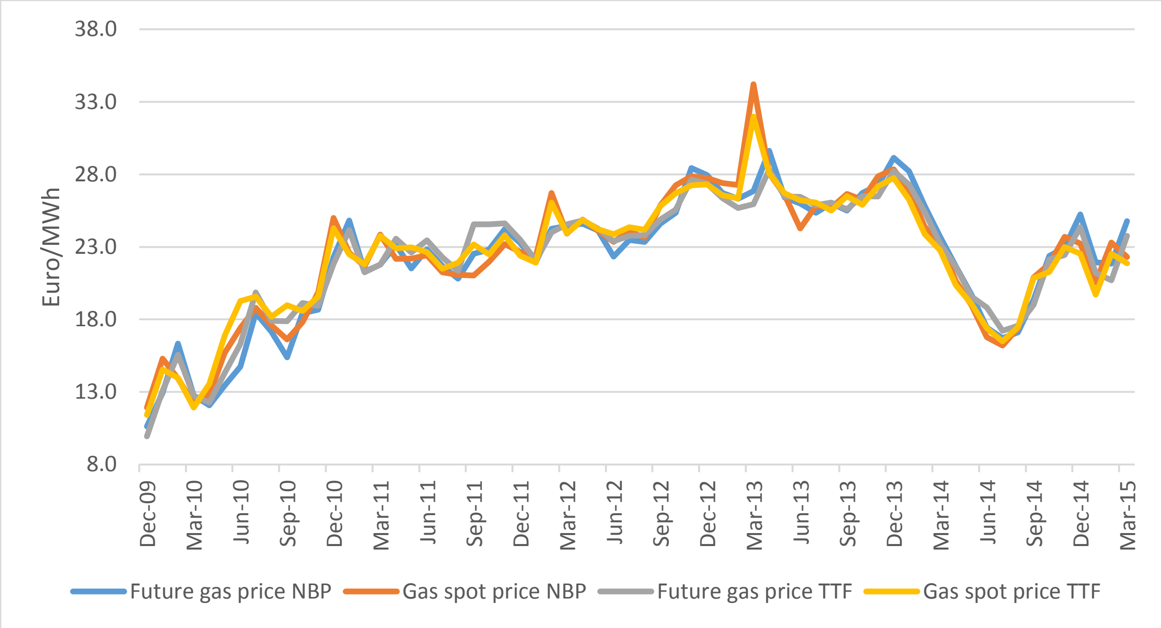


Figure 4.4 Monthly average natural gas spot prices as well as month-ahead natural gas future prices observed on the last trading day for NBP and TTF covering the maturity period from December 2009 to February 2015. Source: Bloomberg

	Month-ahead NBP gas futures prices on the last trading day	**Month-ahead TTF gas futures prices on the last trading day**	**Monthly average gas NBP spot prices**	**Monthly average gas TTF spot prices**
Mean	22.14	22.26	22.37	22.40
Median	22.84	23.45	23.19	22.91
Maximum	29.63	28.33	34.22	31.99
Minimum	10.62	9.93	11.93	11.42
Standard deviation	4.49	4.22	4.49	4.19
Coefficient of variation	0.20	0.19	0.20	0.19
Skewness	-0.72	-0.96	-0.36	-0.64
Kurtosis	2.89	3.38	3.06	3.25

Prices are quoted in Euro/MWh

Table 4.5 Descriptive statistics of monthly average natural gas spot prices as well as month-ahead natural gas future prices observed on the last trading day for NBP and TTF covering the maturity period from December 2009 to February 2015. Source: Bloomberg

Crude oil spot prices

Figure 4.5 shows the time series of monthly average Brent spot prices from December 2009 to February 2015. Table 4.6 lists the main descriptive statistics. We can observe that Brent oil price was increasing until March 2012. Afterwards it kept dropping drastically from maximum 95.0 €/Bbl to less than half the price 41.4 €/Bbl, implying a quite volatile crude oil global market.

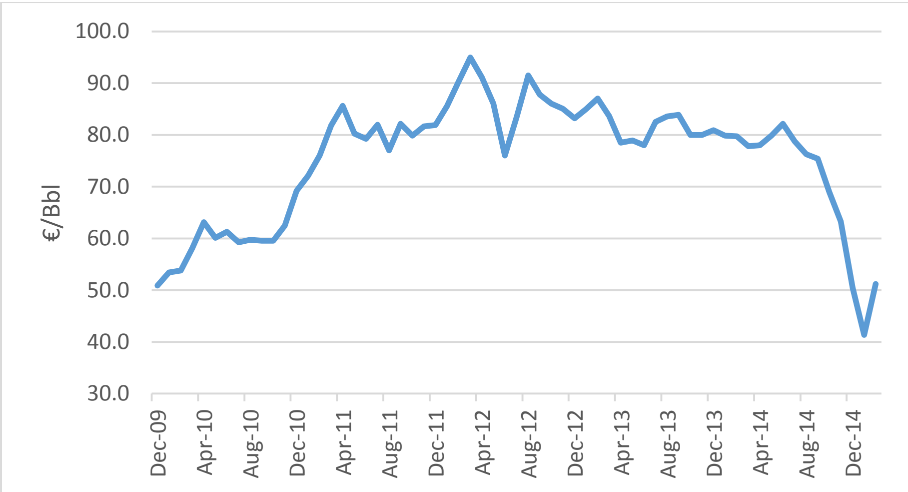


Figure 4.5 Monthly average Brent spot prices from December 2009 to February 2015. Source: Platts

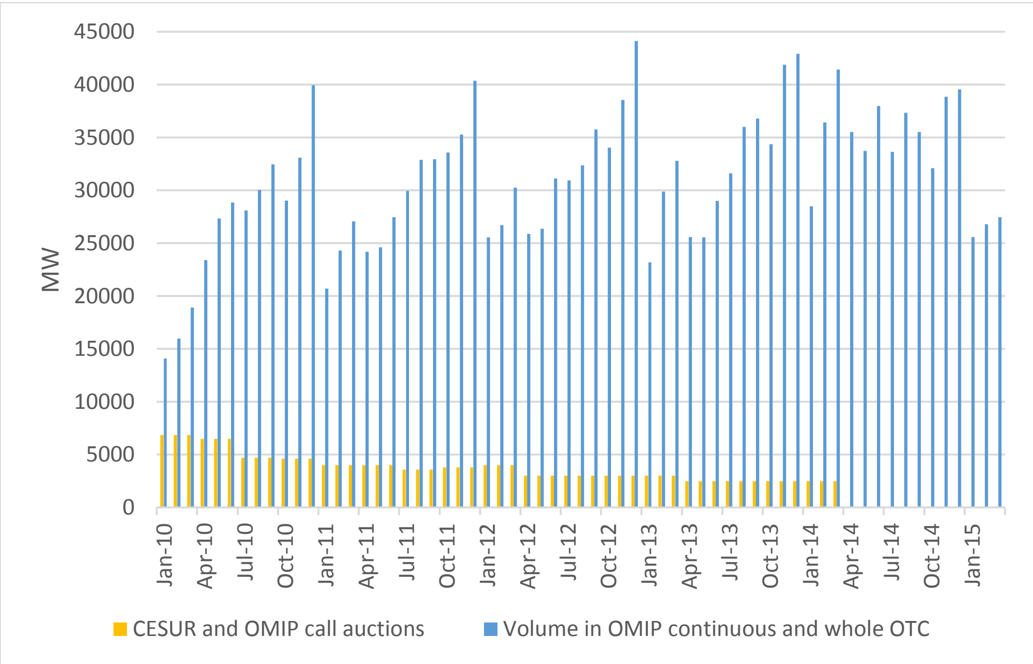
	Mean	Max	Min	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Monthly average Platts Dated Brent spot prices	75.2	95.0	41.4	12.1	0.16	-0.89	2.87

Prices are quoted in €/Bbl

Table 4.6 Descriptive statistics of monthly average Brent spot prices from December 2009 to February 2015. Source: Platts

<u>CESUR & OMIP call auctions and open interest & volume</u>

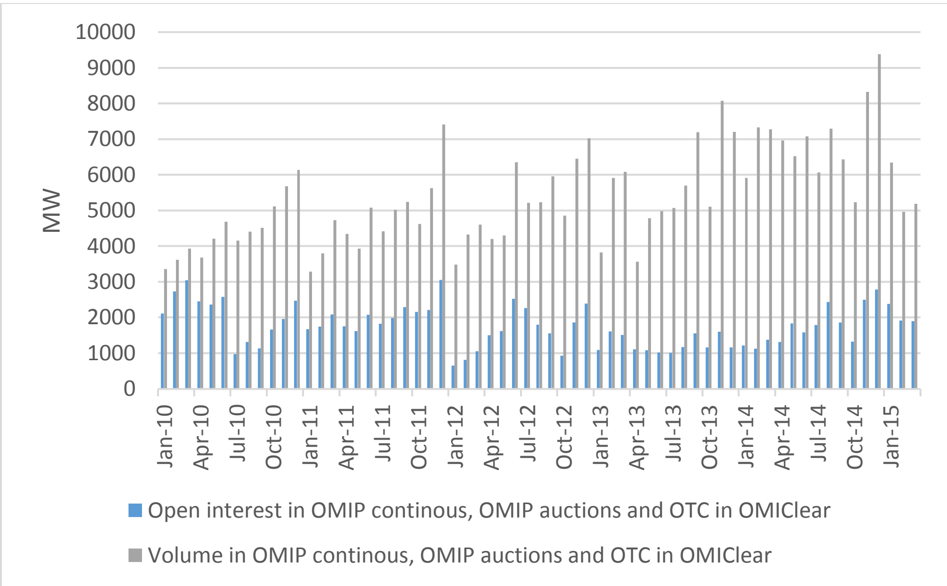
Figure 4.6 displays the evolution of CESUR and OMIP call auctions as well volume traded in OMIP continuous , OTC registered in OMIClear and OTC non-registered for monthly electricity base-load forward contracts covering the maturity period from January 2010 to March 2015. Trading volume excludes OMIP call auctions. We observe that with the decline of CESUR auction and OMIP call auctions, volume in organized and non-organized forward markets is showing constantly growing trend. It suggests that the implementation of OMIP call auction and CESUR auction to some extent fostered the liquidity of Spanish electricity derivatives markets. In addition, after the regression seasonality test of total volume including OMIP continuous, OMIP call auctions, OTC registered in OMIClear and OTC non-registered, it shows that total volume has significant seasonal trends in Q2, Q3 and Q4, while Q1 is found not significant (see Appendix B).



Trades are quoted in MW.

Figure 4.6 The evolution of CESUR and OMIP call auctions as well as volume traded in OMIP continuous, OTC registered in OMIClear and OTC non-registered for electricity base-load forward contracts covering the maturity period from January 2010 to March 2015. Sources: OMEL Mercados, OMIP-OMIClear and brokers

Moreover, open interest on the last trading day and volume traded in OMIP continuous, OMIP call auctions and OTC registered in OMIClear for electricity base-load forward contracts (sum of monthly, quarterly and yearly forward contracts) covering the maturity period from January 2010 to March 2015 are plotted in Figure 4.7. Open interest consists OMIP continuous, OMIP call auction and OTC registered in OMIClear. In forward markets, apart from hedgers, outside speculators can benefit from forward price movements for trading period but they close their open position before delivery. There is empirical evidence available that seems to confirm that hedgers tend to hold their futures market positions longer than speculator. Lucia and Pardo (2010) provides reference of this literature. Around one third the volume in OMIP keeps the position on the last trading day before delivery. This figure suggests show the relative importance of speculative activity in OMIP. Open interest did not show significant seasonal trends (see Appendix B). Table 4.7 lists the main descriptive statistics of open interest and volumes from different markets. It shows that volume from OTC nonregistered counts almost 6 times the rest of the trading volume.



Trades are quoted in MW.

Figure 4.7 The evolution of open interest on the last trading day and volume traded in OMIP continuous, OMIP call auctions and OTC registered in OMIClear for electricity base-load forward contracts covering the maturity period from January 2010 to March 2015. Source: OMIP

	Mean	Min	Max	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Open interest on the last trading day including OMIP continuous, OMIP call auction, OTC registered in OMIClear	1755	650	3052	577.8	0.33	0.26	2.29
Volume including OMIP continuous, OMIP call auction, OTC registered in OMIClear	5410	3289	9385	1357.9	0.25	0.61	2.87
Volume including OMIP continuous, OTC registered in OMIClear	5168	1299	9385	1668.8	0.32	-0.07	2.97
Volume including OMIP continuous, OTC registered in OMIClear, OTC nonregistered	31049	14100	44130	6377.3	0.21	-0.22	2.93
Volume including OMIP continuous, OMIP call auction, OTC registered in OMIClear, OTC nonregistered	31291	16157	44130	6118.7	0.20	-0.08	2.66

Trades are quoted in MW.

Table 4.7 Descriptive statistics of open interest on the last trading day and volume from different markets for electricity base-load forward contracts covering the maturity period from January 2010 to March 2015. Source: OMIP & Brokers

5 Methodology

This part elaborates the methodology adopted in this thesis in order to answer the research questions and to achieve the research objectives mentioned in Chapter 1. Figure 5.1 gives a graphical display of the whole methodology. It is designed by following logical steps. Firstly, raw data sources and initial data analysis are presented to give an overall understanding of the Spanish electricity future markets. Further, a preliminary analysis of the research focus-ex-post forward risk premium is developed. Particularly it examines the existence (magnitude and sign), and behavior (seasonality) of the forward risk premium, as well as testing the B&L model. Based on this preliminary study, a multifactor propositional framework is proposed to identify the main drivers determining the forward risk premium. Lastly regression analysis is performed, in which forward risk premium is regressed against a set of explanatory determinants. Research questions are addressed based on the regression analysis results.

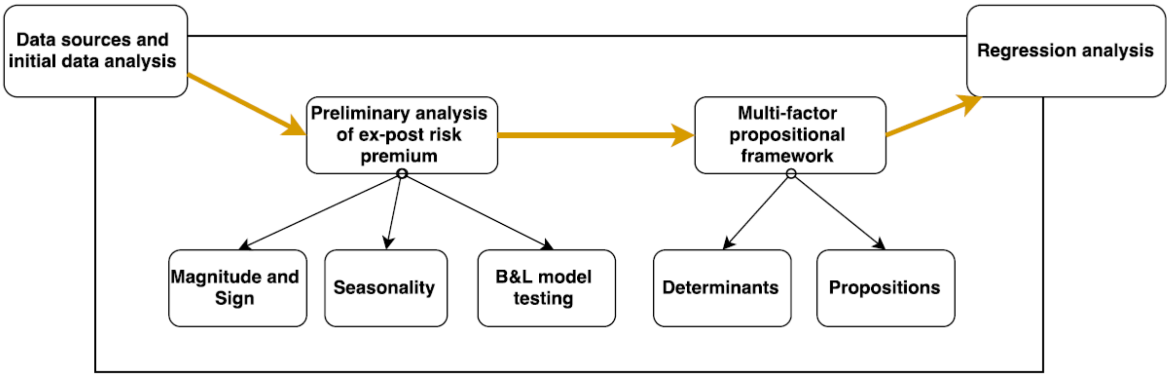


Figure 5.1 Graphical display of research methodology.

5.1 Preliminary analysis of ex-post forward risk premium

In this section, a preliminary analysis of the research objective, ex-post forward risk premium will be presented. Firstly of all, we investigate the main characteristics including the magnitude and sign. Further, the seasonal trend of the risk premium is analyzed. Lastly a similar test based on B&L model will be given.

5.1.1 Magnitude and sign of ex-post forward risk premium

For each monthly contract the relative ex-post forward risk premium will be used, expressed as a percentage of the spot price at maturity. It is formulated as follows:

$$\Delta RP_{t,T} = \frac{F_{t,T} - S_T}{S_T}$$

Equation 5.1

Where $\Delta RP_{t,T}$ is the relative ex-post forward risk premium, $F_{t,T}$ is the settlement price on the last trading day in month t for delivery in T and S_T is the spot price average in month T. Figure 5.2 shows the evolution of relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day covering the maturity period from January 2010 to March 2015.Table 5.1 summarizes the descriptive statistics.

We can observe from Figure 5.2 that relative ex-post forward risk premium is quite volatile during the study period, changing sign and magnitude constantly. It reached the extreme high positive values (exceeded 100%) in April 2013 and February 2014, implying that future price for these two delivery months were more than two times the realized spot prices. In December 2013, the relative ex-post forward risk premium was negative 20%. It should be noticed that sign changing premiums have been identified in previous works. Indeed, Longstaff and Wang (2004) find that the sign of the forward premium varies systematically throughout the day in the PJM electricity market. According to Hirshleifer (1990) and Bessembinder and Lemmon (2002), it is differences in the desire to hedge positions and to diversify risk that explain the market risk premium and its sign. Benth et al. (2008) show the risk premium in the German electricity market can be explained by the level or risk aversion of buyers and sellers.

A rough impression suggests during most of times the relative ex-post forward risk premium was positive, which is also indicated from the positive mean value 9% shown in Table 5.1. According to the literature, we associate situations with a positive market risk premium with markets where the retailers' desire to cover their positions outweighs that of the producers. Conversely situations with a negative market risk premium result when the producers' desire to hedge their positions outweighs that of the retailers. We argue that large risk premium may be explained by hedging pressure of last resort suppliers (i.e. retailers) in CESUR and OMIP auctions.

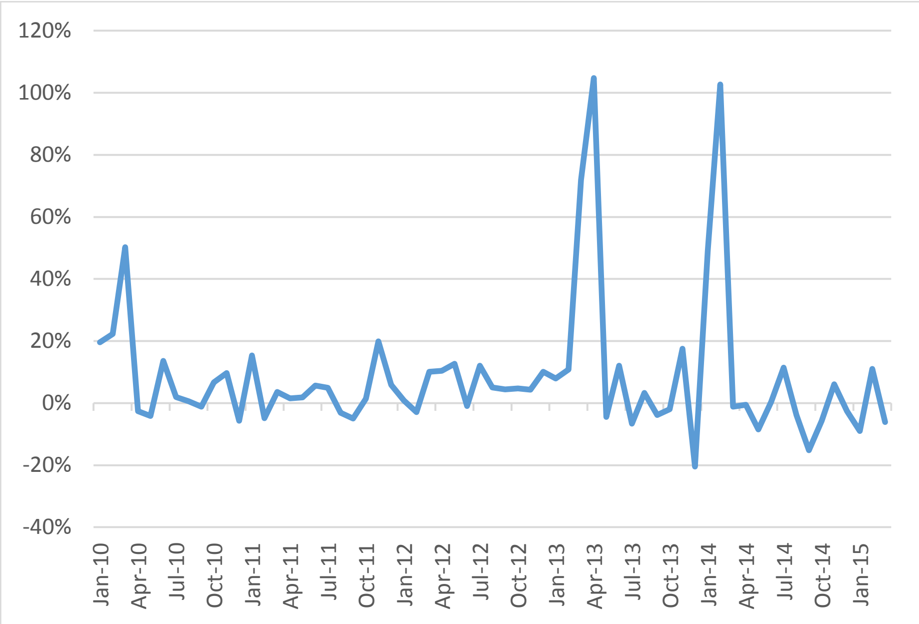


Figure 5.2 Relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day covering the maturity period from January 2010 to March 2015. Sources: OMIE, OMIP-OMIClear and own calculations

	Mean	Max	Min	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Relative ex-post month-ahead base-load forward risk premium on the last trading day	0.09	1.05	-0.20	0.23	2.59	2.87	11.81

Table 5.1 Summary statistics of relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day covering the maturity period from January 2010 to March 2015. Sources: OMIE, OMIP-OMIClear and own calculations

In order to test the presence of non-zero relative ex-post future premium for the electricity base-load month-ahead future contracts, we use the following regression to obtain α, as it is the value of mean future premium, and then we test the null hypothesis, H_0: α=0, and three alternatives H_1: $\alpha \neq 0$, H_2: $\alpha > 0$, H_3: $\alpha < 0$. Results are shown in Table 5.2.

$$\Delta RP_{t,T} = \alpha + \varepsilon_t$$

Equation 5.2

We rejected the null hypothesis, accepted double-side hypothesis H_1 (at the 1% level) and one-side hypothesis H_2 (at the 1% level). Hence we can conclude that the mean of relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day covering the maturity period from January 2010 to March 2015 is significantly different from zero, moreover significant positive with the value 8.7%. It suggests a contango situation in Spanish electricity markets, which means there exists a positive risk premium that market agents are willing to pay for reducing risk exposure. It also implies that there is still significant positive errors between future prices and realized spot prices despite of using future prices on the last trading day, which should give market agents more information about the conditions during the delivery month.

	Sample January 2010 to March 2015
	H_0: α=0
α	0.087
t-statistic	3.06
$\boldsymbol{H_1: \alpha \neq 0}$	$\Pr(\lvert T\rvert > \lvert t\rvert) = 0.0033$
$\boldsymbol{H_2: \alpha > 0}$	$\Pr(T > t) = 0.0016$
$\boldsymbol{H_3: \alpha < 0}$	$\Pr(T < t) = 0.9984$

The t-statistic reported is based on the one-sample mean-comparison test $\Delta RP_{t,T} = \alpha + \varepsilon_t$

Table 5.2 T test for the presence of relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day covering the maturity period from January 2010 to March 2015.

5.1.2 Seasonality of ex-post forward risk premium

In previous sections we found there are seasonal trends in electricity demand and trading volume. In this part the seasonality effects in relative ex-post forward risk premium will be analyzed. First of all, monthly average of absolute and relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day per delivery month from January 2010 to March 2015 is plotted in Figure 5.3.

Noting from visual inspection a seasonal pattern seem to exist in both the absolute and relative forward risk premium, being highest in cold seasons February and March and lowest in the mid seasons May and September. However results from the regression tests based on seasonal dummies indicate that there are no significant seasonal effects in the ex-post month-ahead base-load forward risk premium-for both the absolute and relative forward risk premium (see Appendix C), and therefore not elaborated further.

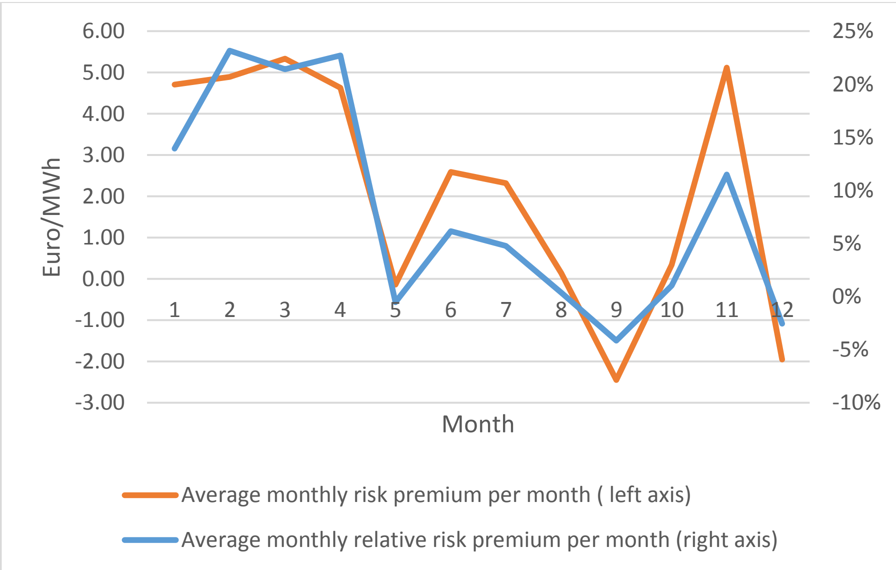


Figure 5.3 Monthly average of absolute and relative ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day per delivery month from January 2010 to March 2015. Sources: OMIE, OMIP-OMIClear and own calculations

5.1.3 Empirical study of Bessembinder and Lemmon model

As one of the most influential researches on electricity risk premium, Bessembinder and Lemmon (2002) presented an equilibrium model of electricity prices that incorporates many realistic economic features of electricity markets. They show that the forward premium (i.e. the difference between forward and expected spot prices) is a function of the variance (negative relation) and skewness of spot prices (positive relation) during the delivering time. Hence the model of B-L assumes rational expectations implying efficient spot price forecasts. In turn, these moments of the spot price distribution serve as risk assessment of market participants. However since the sign of the relative differences changes over time which cannot be explained by risk considerations only (see Figure 5.2), misjudgment of future fundamental generation and demand conditions by market actors have to be considered (Redl, Haas, Huber, & Böhm, 2009).

Hence, instead of assuming rational expectations, the analysis in this thesis is based on testing a myopic expectation formation which means market participants form adaptive expectation of spot prices based on current spot prices (Douglas & Popova, 2008). The following equation is estimated by OLS in order to test the empirical implications of the Bessembinder and Lemmon (2002) model.

$$F_{t,T} - S_T = b1 + b2Var(S_t) + b3Sknew(S_t) + \varepsilon_t$$

Equation 5.3

here $F_{t,T}$ is the settlement price on the last trading day in month t for delivery in T and S_T is the spot price average in month T, $\mathrm{F_{t,T}} - \mathrm{S_T}$ is the ex-post risk premium, $\mathrm{S_t}$ is the spot price average during month t. $\mathrm{Var(S_t)}$ and $\mathrm{Skew(S_t)}$ are the respective variance and skewness of daily spot prices in month t. Results are shown in 04. We notice that positive sign for the variance of spot prices, and negative sign for the skewness of spot prices. All coefficient estimates are significant at the 1% level. The adjusted R^2 shows that the model can explain 26% of the variance of the forward risk premium. This founding is interestingly, just opposite to the B-L predictions. Our model suggests that ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day, is positively related to the variance of spot prices and negatively related to skewness of spot prices. This is similar as the results presented in Lucia and Torró (2011) that analyzed the NordPool forward risk premium from weeks 21 in 2003 to week 43 in 2007.

[4] Regression equation 5.3 with variance and skewness of spot prices in month T is also estimated. Results can be seen in Appendix D. However they do not confirm to the findings of Bessembinder and Lemmon model as well.

In fact, many empirical studies before confirm the implications of the B-L model only partially or do not confirm at all (like in our case). Handika and Trueck (2013) do not confirm the B–L model for Australian data, with coefficients being often insignificant or of other sign than expected. Redl et al. (2009), who analyze EEX and Nord Pool data give very weak support of the B– L model obtaining, as expected, a positive skewness coefficient for EEX, but insignificant coefficients of mixed signs in all other cases.

To summarize, our empirical performance does not confirm the Bessembinder-Lemmon model, with unexpected coefficients signs and weak explanatory power. It suggest that analyses of the forward premium as a single function of the spot price stochastics may be insufficient due to the fact that the signs of risk premium cannot be explained by risk considerations only. Hence, in the following a categorization of future premium determinants is proposed which takes into account the risk assessment of the market participants and, moreover, includes more comprehensive factors that influence spot and future prices (supply and demand characteristics, market hedging and speculative activities, regulatory implementations and other commodity markets). Within each category several explanatory variables are described which give further insights on the propositions on the electricity forward premium.

Panel A	**b1**	**b2**	**b3**	**N**
Coefficient	-1.149	0.026*	-1.498*	63
t-statistic	-1.38	0.006	0.512	
Panel B	Adj.R^2	AIC	BIC	D-W
	0.26	384.38	390.81	2.05

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1%(5%, 10%) level.

$$F_{t,T} - S_T = b1 + b2Var(S_t) + b3Sknew(S_t) + \varepsilon_t$$

Table 5.3 Results of regression analysis (5.3) for ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day per delivery month from January 2010 to March 2015. Sources: OMIE, OMIP-OMIClear and own calculations

5.2 A multifactor propositional framework

In this chapter, a multifactor propositional framework is presented to help explain the characteristics and behaviors of ex-post forward risk premium. It is built on the Bessembinder-Lemmon equilibrium model, which identifies the stochastics of spot prices as the risk assessments for market agents. Moreover this framework does not assume perfect forecast of spot prices, instead considers the adaptive expectation formation from market participants. It provides a more comprehensive analysis of electricity risk premium by introducing more influencing factors, hence helps address the questions cannot be explained by risk considerations only.

5.2.1 Determinants

The main determinates that influence ex-post forward risk premium will be described in this section. Literatures have discovered different factors in different electricity markets in order to explain the characteristics and behaviors of forward risk premium. Douglas and Popova (2008) obtained results for the PJM market which are in line with the predictions of the B–L model expanded to include the availability of stored gas, which they claim to be an important factor in determining the size of the risk premium. Botterud et al. (2010) included the level of water reservoir in the model when analyzing the hydro-dominated Nordic electricity market. This thesis has chosen the work of Redl and Bunn (2013) as the main reference due to the reason that it suggests a more integrated and general categories of factors, covering fundamental influences, behavioral effects, shock effects, dynamic effects and etc. Furthermore, we extend their work by introducing a new category: market hedging, speculative activities and liquidity. It is of significance to help understand the market agents' behaviors and the link with forward risk premium. Lastly, as this study is based on Spanish electricity market, the effects of domestic regulatory instruments implemented by Spanish government on market outcomes will be investigated. Below determinants are described in more details under their each category. Table 5.4 summarizes all the determinants.

<u>Fundamental influences</u>

Ex-post gas risk premium

Similar to the definition of ex-post electricity risk premium, ex-post gas risk premium is obtained as the difference between gas future prices during the trading period and realized gas spot price for the maturity period. As mentioned in Chapter 4, we choose two natural gas indices, respectively gas NBP and gas TTF. In order to allow a better comparison between power and gas market, the relative ex-post gas risk premium is formulated as follows:

$$\Delta RP_{Gas\ t-1,t} = \frac{F_{Gas\ t-1,t} - S_{Gas\ t}}{S_{Gas\ t}}$$

Equation 5.4

Specifically, we focus on month-ahead natural gas future prices settled on the last trading day of trading month t-1 for delivery in month t, and monthly average natural gas spot prices during delivery month t.

Scarcity

The reserve margin as the ratio of generation and demand provides a measurement for scarcity in the electricity supply systems. Particularly, we are interested in the intermittent energy sources, namely renewable energy sources (RES). Hence the scarcity is defined as follows:

$$margin_t = \frac{RES_t}{Demand_t}$$

Equation 5.5

Where $margin_t$ is the observed reserve margin at the end of the trading month t, RES_t and $Demand_t$ are the respective monthly average renewable energy generation and demand for the trading month t.

Behavioral effects

We choose three indices to measure the behaviors of spot prices, which are of important for the risk assessments of market agents.

Spot price volatility[5]

In order to compare the volatilities across different markets (i.e. oil and power market) the coefficient of variation (CV) is applied instead of the actual value of variance. It is defined as the ratio of the standard deviation of daily spot prices to the average spot prices during the trading month t. It shows the extent of variability in relation to the mean of the spot prices.

Spot price skewness

The skewness of the spot prices is obtained as the moment coefficient of skewness for the daily spot prices during the trading month t. It is a measure of symmetry. Spot prices distributes symmetrically if the skewness equals to zero. Positively skewed spot prices indicate that spot prices distribution has a long right tail, meaning a greater chance of extremely positive outcomes(price spikes), and vice versa.

Spot price kurtosis

The kurtosis of spot prices can be formally defined as the standardized fourth population moment about the mean of the daily spot prices during the trading month t. It refers to the degree of peak in the spot prices distribution. Kurtosis equals to three means a normal distribution. When the value is above 3, spot prices has a distribution with more peak than normal, implying that the distribution has fatter tails and therefore there are higher chances of extreme outcomes on both positive and negative sides, and vice versa.

Oil price changes

The oil price changes is measured by the relative difference between average daily Brent oil prices in month t and average daily Brent oil prices in month t-1. It is formulated as follows:

$$\Delta Brent_{\,t} = \frac{Brent_t - Brent_{t-1}}{Brent_{t-1}}$$

Equation 5.6

[5] In this thesis, volatility is measured by the coefficient of variation (CV) instead of variance. CV is defined as the ratio of the standard deviation to the mean. CV is used for comparison between data sets with different units or widely different means.

Dynamic effects

Basis

The basis is defined as the difference between electricity future prices and current spot prices. To distinguish from the electricity future premium, basis is based on the observed spot prices during the trading month t, while risk premium is based on the realized spot prices at future maturity month T. Basis captures the dynamic behaviors of risk premium. The formula is shown as follows:

$$\Delta Basis_t = \frac{F_{t,T} - S_t}{S_t}$$

Equation 5.7

Where $F_{t,T}$ is the settlement price of base-load month-ahead future contracts on the last trading day in month t for delivery in month T, S_t is the spot price average in month t, $\mathrm{F_{t,T}} - \mathrm{S_t}$ thus is the basis for month t, $\Delta Basis_t$ is expressed as a ratio of basis over average spot price in month t.

Market hedging, speculative activities and liquidity

Open interest and trading volume can be used as the measurements of hedging, speculative activities and liquidity in the Spanish electricity future market.

Open interest

Open interest equals the number of outstanding long positions (or equivalently, short positions) at the end of the day. There is limited information about OTC non-registered power transactions (it is only known the type of contracts, volumes and transaction prices, through the information voluntarily submitted by the main brokers to CNMC). Therefore open interest for contracts traded in OTC market but non registered on central counterparty is not known. Hence in this thesis, open interest takes OMIP continuous market, OMIP call auctions and OTC registered in OMIP into account. The ratio of open interest in OMIP at the last trading day of month t for month-ahead future base-load contracts delivered in month T and the volume traded and registered in OMIClear for base-load monthly, quarterly and yearly contracts covering delivery month T, is used as the determinant to measure the hedging and speculative activities in OMIP during month t.

Trading volume

The ratio of volume traded in forward markets for base-load future contracts delivered in month T to the total demand during the trading month t, is used as the determinant to measure the liquidity of the forward market in month t. The volume consists of the trades in OMIP continuous market and OTC markets (OTC registered in OMIP and non-registered OTC) , excluding OMIP call auctions.

Regulatory instruments

OMIP call and CESUR auctions

The ratio of total OMIP call and CESUR auctions for month-head future base-load contracts delivered in month T to the total demand during the trading month t, is chosen to represent the effect of these two regulatory instruments on the market liquidity in month t.

Shock effects

Margin shock

Above these, all the determinants described are observable for market participants on the trading days in month t for the month-ahead base-load future contacts delivered in month T. Here we introduce another determinant that captures the changes of supply and demand during the delivery month T. It will contribute to the explanation of the futures-spot difference caused by the misjudgment of future generation and demand conditions from market agents. It is formulated as follows:

$$Margin_T = \frac{RES_T}{Demand_T}$$

Equation 5.8

Where $Margin_T$ is the realized reserve margin during the delivery month T, RES_T and $Demand_T$ are the respective monthly average renewable energy generation and demand during the delivery month T.

5.2.2 Propositions

Below a set of propositions is presented based on the determinants chosen under each category (fundamental influences, behavioral effects, dynamic effects, market hedging, speculative activities and liquidity, regulatory instruments and shock effects) to explain the characteristics and behaviors of ex-post electricity risk premium. These propositions contribute understanding the main drives of the forward risk premium in Spanish electricity market.

Fundamental influences

Proposition 1: An increase in the natural gas forward risk premium is expected to increase the electricity forward risk premium.

The gas risk premium is suspected to impact the electricity risk premium since most of the systematic variation in demand levels across the year in the Spanish electricity market is met using CCGT and hydroelectric power when the renewable production is reduced. Moreover, interconnections to other European markets, like EEX market with a high importance of fossil fueled generation technologies also contributes to this hypothesis. Specifically, it will positively influence the electricity forward risk premium. It can be explained by either the risk management considerations of generators because of the realized gas premium constitutes the risk exposure of generators contracting gas previously, or the hedging pressure from retailers who are afraid of excessive electricity prices, or the forecast errors of the market agents.

Proposition 2.A: Decreasing observed reserve margin increases the forward risk premium.

A reduction in the observed reserve margin, as an indicator of relative scarcity, can be caused either by unexpected decrease of renewable energy generation, or demand shocks during the trading month t. Following the myopic approach's interpreting that market agents form the adaptive expectation, a perceived decreasing reserve margin induces expected spot prices and therefore forward prices and, correspondingly, risk premium to increase.

Proposition 2.B: Increased volatility of observed reserve margin negatively/ positively influences the forward risk premium.

Similar to the explanation in Proposition 3.A, an increased volatility of observed reserve margin leads market agents to expect higher spot prices volatility. It could cause the risk premium to decrease if there is more hedging pressure from sellers to reduce variability in their profits compared to the buyers with the risk aversion in terms of price volatility, and vice versa.

Behavioral effects

Proposition 3.A: Spot price volatility negatively/ positively influences the forward risk premium.

Producers are concerned with both the mean and the variance of their profits. For this reason producers can benefit from hedging market risks, because excessive volatility could increase the expected costs of financial distress and can lead to suboptimal investment. Therefore, producers could sell forward contracts so as to reduce variability in their profits. Hence the regression coefficient associated with the spot price volatility could show a negative sign if this selling hedging pressure is important. Notice that the hypothesis also could be the opposite if there is more hedging pressure from retailers who want to lock the prices.

Proposition 3.B: Spot price skewness positively influences the forward risk premium.

In line with the equilibrium model in Bessembinder and Lemmon (2002), spot price skewness provides risk assessments for market agents, resulting in a positive influence on risk premium. Particularly, spot prices with a high positive skewness at current month send signals to market participants that there are high chances of price spikes in the future. Hence it increases the hedging demand of retailers to obtain secured retailing prices. On the other hand, positively skewed spot prices (i.e., positive price spikes) work to the advantage of the producer, and he will be more reluctant to enter forward contracts that misses opportunities where he might be better off selling in the spot market. Both factors contribute to a positive forward premium. Hence the regression coefficient associated with the skewness could show a positive sign.

Proposition 3.C: Spot price kurtosis negatively/ positively influences the forward risk premium.

Spot prices with a high kurtosis has the distribution with more peak than normal, implying that the distribution has fatter tails and therefore there are higher chances of extreme outcomes on both positive and negative sides, and vice versa. In this sense, the regression coefficient associated with the kurtosis could show a negative sign if producers are concerned with the variability of their profits. On the other hand spot price kurtosis could also positively influence the forward risk premium given more buying hedging demand of spot price volatility (see explanation about proposition 3.A).

Proposition 4: Increased oil prices increases the electricity forward risk premium.

According to the study developed by European Parliament for the impacts of oil prices on EU energy prices (Parliament, 2015), natural gas, coal, electricity, and oil product prices more or less clearly move parallel to the oil price. Correlation of the oil price with gas prices is strong (both for import prices and for spot prices), slightly weaker with steam coal, and very strong for oil products, whereas electricity only correlates moderately with the oil price.
As oil prices dominates the energy commodities in general, it is expected that increased oil prices (positive price changes) increases the expected electricity prices, and therefore increases the electricity forward risk premium.

Dynamic effects

Proposition 5: An increase in basis is expected to decrease the electricity forward risk premium.

Basis has been applied to various markets to formulate the forward prices[6]. Lucia and Torró (2011) and Redl and Bunn (2013) all used the basis in their risk premium evaluation in NordPool and EEX, respectively. The sign of the basis coefficient depends on the time of year in Lucia and Torró (2011) and is positive in Redl and Bunn (2013). We propose that an increasing basis will cause a decrease to the electricity forward risk

[6] Fama and French (1987) applied the basis as a regressor on agricultural, wood, animal and metal commodities.

premium in Spain based on adaptive expectation formation. It is not surprising that current month-ahead future prices are positively correlated with current spot prices. Because with myopic expectations, market agents faced with the challenge of forming month-ahead spot prices forecasts, may adapt expectations to the recent average spot prices. With a simple regression test, we find that future price increases 0.6 Euro/MWh to 1 Euro/MWh change in current spot price, hence the basis is negatively correlated to current spot price (see Appendix E). Ultimately, it is expected that ex-post risk premium is negatively influenced by the basis.

Market hedging, speculative activities and liquidity

Proposition 6.A: Open interest negatively/positively influences the forward risk premium.

As the market volatility increases, producers could sell forward contracts so as to reduce variability in their profits. Thus, spot price variance would induce short hedging pressure in order to reduce profit variability. Since lower forward prices could incentive a larger pool of market participants (outside speculators). Outside speculators could have lower attached to being in the market than existing participants, but are enticed to enter the forward market when benefits outweigh the entry costs. This equilibrium is characterized with higher open interest, lower futures prices and lower risk premium. Chen et al. (1995) test a theoretical model of the risk premium and open interest of stock index futures and the empirical results are consistent with these predictions. However in this thesis we focus on the open interest on the last trading day before delivery. So the ratio between open interest and volume traded in the same month can be used as the measurement of hedging and speculative activities. Taking the most extreme cases, there exists only speculative activities if the ratio is equal to 0, only hedging activities if the ratio is equal to 1. The question about how the hedging activities would influence the forward prices, it again depends on if the hedging pressure is more from producers or from retailers. In the case that there is more hedging pressure from producers who are willing to accept lower future prices in order to reduce profit variability, it leads to lower risk premium. On the other hand there is more hedging pressure from retailers seeking price stability, the risk premium will increase.

Proposition 6.B: An increasing trading volume causes the forward risk premium to decrease.

Market liquidity may play a key role in moving prices to “fair” values (as given by the spot price of delivery time) since market liquidity may enhance the efficiency of the forward pricing system. Schwartz and Subrahmanyam (2007) test these ideas by studying the aggregate liquidity on the NYSE[7]. Moreover, the interaction between distinct classes of traders, producers ("hedgers") and outsiders (“speculators") may help reduce the risk premium since risks concentrated among a few traders should be more influential for pricing than dispersed risks (Hirshleifer, 1990). It is likely that more distinct classes of traders are associated with more liquidity. Therefore, the regression coefficient associated with liquidity (i.e., trading volume) could show a negative sign.

Regulatory instruments

Proposition 7: Forward risk premium is positively influenced by the matched volumes in regulated auctions (CESUR and OMIP call auctions).

CESUR (Contracts of Energy for the Last Resort Supply) and OMIP auctions were a compulsory purchase mechanism for the last resort suppliers (price-inelastic demand). The auction prices were used as the estimated forward energy cost in the price formula for the last resort tariff. The products purchased by the last resort suppliers in the CESUR and OMIP auctions were standard forward contracts (base load and peak products) also traded in the forward markets. In this sense, there is a strong interrelation between the resulting equilibrium price in these auctions and the price formation in the existing organized and non-organized markets (OMIP and OTC markets).The price inelastic demand of last resort suppliers in CESUR and OMIP auctions adds hedging pressure that could have promoted an upward bias in the forward prices viewed as a predictor of the spot price.

[7] NYSE refers to New York Stock Exchange.

Shock effects

Proposition 8: Margin shocks positively influence the forward premium.

Margin shocks, defined as the realized ratio of renewable energy generation to demand during the delivery month T, contribute to the explanation of the futures-spot difference which cannot be understood based on the risk assessments from the market agents only. It represents the misjudgment of future generation and demand conditions by market agents at trading month t. A higher margin shocks causes lower realized spot prices, and higher ex-post forward risk premium.

Category	Determinants	Influence on forward risk premium	Definition
Fundamental influences	Natural gas forward risk premium	Positive	Observed relative natural gas forward risk premium for delivery in month t
	Observed reserve margin	Negative	Observed ratio of renewable energy generation to the demand during trading month t
	Volatility of observed reserve margin	Negative/ Positive*	The coefficient of variation of reserve margin during trading month t
Behavioral effects	Spot price volatility	Negative/ Positive*	The coefficient of variation of spot prices during trading month t
	Spot price skewness	Positive	Skewness of spot prices during trading month t
	Spot price kurtosis	Negative/ Positive*	Kurtosis of spot prices during trading month t
	Oil price changes	Positive	The relative differences between average daily Brent oil prices in month t and average daily Brent oil prices in month t-1
Dynamic effects	Basis	Negative	Relative difference between month-head future prices on the last trading day to the average spot prices during trading month t
Market hedging, speculative activities and liquidity	Open interest	Negative/ Positive*	Ratio of open interest in OMIP at the last trading day of month t for future base-load contracts covering delivery month T and the volume traded and registered in OMIClear of base-load monthly, quarterly and yearly contracts covering delivery month T (Open interests considers OMIP continuous market, OMIP call auctions and OTC cleared by OMIClear)

	Trading volume	Negative	Ratio of volume traded in OMIP continuous and OTC(registered and non-registered) for future base-load contracts covering delivery month T to demand during trading month t
Regulatory instruments	Regulated auctions volume	Positive	Ratio of total OMIP call and CESUR auctions for month-head future base-load contracts delivered in month T to demand during trading month t
Shock effects#	Margin shocks	Positive	Realized ratio of renewable energy generation to demand during the delivery month T

All determinants besides shock effects are observable for market agents during trading month t, shock effects is obtained during delivery month T.

* Determinants including Volatility of observed reserve margin, Spot price volatility, Spot price kurtosis, and Open interest could have both negative and positive influence on the risk premium. It depends on the hedging pressure is more from producers or from retailers. If more from producers then the sign is negative.

Table 5.4 Summary of forward risk premium determinants.

6 Regression analysis of the ex-post forward premium

In this chapter, ordinary least squares (OLS) regression analysis is conducted to test the set of propositions proposed in Chapter 5. As a result, a more specific model is generated to explain the determinants influencing the ex-post base-load forward risk premium in Spanish electricity market. The regression models including the general and specific regression model are presented firstly, afterwards results interpretations are given.

6.1 The general regression model

The first regression model including all the determinants listed in Table 5.4 is formulated as follows:

$$\begin{aligned}\Delta RP_{Power\ t,T} = {} & b0 + b1\Delta RP_{Gas\ t-1,t} + b2margin_t + b3Sknew(S_t) \\ & + b4\Delta Brent_t + b5Auction_{t,T} + b6Margin_T \\ & + b7Trade_{t,T} + b8\Delta Basis_t + b9C_v(margin_t) + b10C_v(S_t) \\ & + b11Kurt(S_t) + b12Open_{t,T} + \varepsilon_{t,T}\end{aligned}$$

Where

$$\Delta RP_{Power\ t,T} = \frac{F_{t,T} - S_T}{S_T}$$

$$\Delta RP_{Gas\ t-1,t} = \frac{F_{Gas\ t-1,t} - S_{Gas\ t}}{S_{Gas\ t}}$$

$$\Delta Basis_t = \frac{F_{t,T} - S_t}{S_t}$$

$$margin_t = \frac{RES_t}{Demand_t}$$

$$Margin_T = \frac{RES_T}{Demand_T}$$

$$\Delta Brent_t = \frac{Brent_t - Brent_{t-1}}{Brent_{t-1}}$$

$$Auction_{t,T} = \frac{(CESUR + OMIP\ Call)_T}{Demand_t}$$

$$Trade_{t,T} = \frac{Trade_T}{Demand_t}$$

$$Open_{t,T} = \frac{Open_{t,T}}{Trade_T}$$

Equation 6.1

In which $F_{t,T} - S_T$ is the ex-post electricity risk premium, $F_{t,T}$ is the base-load monthly future price on the last trading day in month t for delivery in month T (equals to t+1), S_T is the realized spot price average in month T, $\Delta RP_{Power\ t,T}$ (relative ex-post electricity risk premium) is the ex-post electricity risk premium over S_T . Similarly, $F_{Gas\ t-1,t} - S_{Gas\ t}$ is the ex-post gas risk premium, $F_{Gas\ t-1,t}$ is the monthly gas future price on the last trading day in month t-1 for delivery in month t, $S_{Gas\ t}$ is the spot price average in month t, $\Delta RP_{Gas\ t-1,t}$ is the ex-post gas risk premium over $S_{Gas\ t}$. $margin_t$ is the observed ratio of renewable energy generation to demand in month t, $C_v(margin_t)$ is the corresponding coefficient of variation. $C_v(S_t)$, $Sknew(S_t)$ and $Kurt(S_t)$ are the respective coefficient of variation, skewness, kurtosis of the daily electricity spot prices in month t. $\Delta Brent_t$ is the relative difference between average daily Brent oil spot prices in month t and average prices in month t-1. $Basis_t$ is the difference between the monthly base-load future prices on the last trading in month t for delivery in month T ($F_{t,T}$) and the spot average price in month t (S_t) over S_t.

$Open_{t,T}$ is the open interest on the last trading day in month t for future base-load contracts delivered in month T over the volume traded and registered in OMIClear for base-load monthly, quarterly and yearly contracts covering delivery month T. $Trade_{t,T}$ is the volume of future base-load monthly, quarterly and yearly contracts covering delivery month T over demand in month t. Open interest includes trades in OMIP continuous, OMIP call auctions and OTC registered in OMIP for clearing by OMIClear, while volume consists the trades in OMIP continuous and OTC market (registered in OMIP and non-registered). $Auction_{t,T}$ is the ratio of total OMIP call and CESUR auctions volume for month-head future base-load contracts delivered in month T to the demand in month t. Lastly $Margin_T$ is the margin shock in month T, as the realized ratio of renewable energy generation to demand in month T. Noticeably, besides $Sknew(S_t)$, $Kurt(S_t)$, the rest variables are all expressed as ratio.

Regression results are presented in Table 6.1. Firstly the overall model is significant at the 1% level with F-statistic equals to 3.12. Moreover the adjusted R^2 is 0.52, indicating that 52% of the variability of dependent variable-relative electricity risk premium, is accounted for by those independent variables in the model. DW is close to 2, imply that there is no first-order serial correlation among the residuals.

Now we take a close look at the coefficient of each determinant. Determinants with significant coefficients are respectively, oil price changes (5% level), CESUR and OMIP actions (5% level), margin shock (10% level), basic (1% level), the coefficient of variance of scarcity(10% level) and the coefficient of variance of spot prices (5% level). In addition, the signs of coefficients for CESUR and OMIP actions, margin shock and basis are in line with the propositions proposed in Chapter 5. Specifically, CESUR and OMIP actions and margin shock, show expected positive influence on relative electricity risk premium. Basis shows expected negative influence on risk premium. According to our assumptions, the impacts of the reserve margin volatility and the spot prices volatility on risk premium should be the same-either both negative given more hedging pressure from producers or both positive assuming more hedging pressure from retailers. The regression results suggest that increased spot prices volatility causes risk premium to increase, implying that there might be more hedging pressure from retailers, while the coefficient of variation of reserve margin gives the opposite results but less significant. Lastly the oil price changes does not show positive influence on electricity risk premium as we expected. Contrarily, increasing oil price seems to induce decreasing risk premium.

Since those determinants with significant coefficients are all expressed in ratio, we can compare the strength of each coefficient to the dependent variable of our model. Specifically, 1% change in CESUR and OMIP auctions leads to largest change of relative risk premium (1.26%), followed by coefficient of variation of reserve margin(1.00 %), coefficient of variation of spot prices (1.00%), margin shock(0.93%), basis (-0.77%) and oil price changes (-0.67%).

So far we tested the general regression model with all the proposed determinants included. Results suggested that parts of the determinants proposed have shown significant influences on the ex-post electricity risk premium, while the rest did not. Moreover, risk premium responds as expected to the changes of those determinants with significant coefficients, with oil price changes and reserve margin volatility as the exceptions. The adjusted R^2 shows that model has a high explanatory power. As a whole, we can conclude that the regression results confirm partially the multifactor propositions framework. It suggests that the determinants proposed contribute to the explaining and understanding of the ex-post forward risk premium in Spanish electricity market. In the next step, a more specific regression model is presented so as to improve its reliability and persuasibility.

Coefficient	Variable	Base-load	Hypothesis
b0	Constant	-0.38(-1.42)	
b1	Relative gas risk premium t[8]	-0.53(-0.94)	+
b2	Reserve margin t	0.40(0.65)	-
b3	Skewness of spot price t	-0.12(-1.54)	+
b4	Changes of Brent t	**-0.67(-2.33)****	+
b5	Auctions t	**1.26(2.56)****	+
b6	Margin shock T	**0.93(1.80)***	+
b7	Volume t	-0.10(-1.15)	-
b8	Basis	**-0.77(-2.81)*****	-
b9	CV of margin t	**-1.00(-1.64)***	-/+
b10	CV of spot price t	**1.00(2.18)****	-/+
b11	Kurtosis of spot price t	-0.03(-1.51)	-/+
b12	Open interest t	0.01(0.05)	-/+
Adjusted R^2		0.52	
AIC		-29.81	
DW		1.72	
F-statistic		3.12	
Observations		63	

Table 6.1 Results of regression analysis (6.1) for ex-post month-ahead base-load relative forward risk premium based on future prices settled on the last trading day covering delivery month from January 2010 to March 2015(t-statistics in brackets). The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). AIC represents the Akaike´s Information Criterion, and DW means the Durbin–Watson d statistic[9]. *** (**,*) indicates significance at the 1% (5%, 10%) level.

[8] The gas risk Premium is based on gas NBP, for gas TTF we obtain the similar results.

[9] The Durbin-Watson Statistic is used to test for the presence of first order serial correlation among the residuals. The value of the Durbin-Watson statistic ranges from 0 to 4. As a general rule of thumb, the

6.2 The specific regression model

Based on model 6.1, a more specific regression model is generated as follows by sequentially minimizing the Akaike´s Information Criterion (AIC). Results for the corresponding model are shown in Table 6.2.

$$\Delta RP_{Power\ t,T} = b0 + b1\Delta Brent_t + b2Auction_{t,T} + b3Margin_T + b4\Delta Basis_t + b5C_v(S_t) + \varepsilon_{t,T}$$

Equation 6. 2

Where $\Delta RP_{Power\ t,T}$ is the relative electricity risk premium for month-ahead base-load future contracts delivered in month T, $\Delta Brent_t$ is the relative difference between average daily Brent oil spot prices in month t and average prices in month t-1. $Auction_{t,T}$ is the ratio of total OMIP call and CESUR auctions volume for month-head future base-load contracts delivered in month T to the demand in month t. $Margin_T$ is the margin shock in month T, as the realized ratio of renewable energy generation to demand in month T. $C_v(S_t)$ is the coefficient of variation of the daily electricity spot prices in month t. $Basis_t$ is the relative difference between the monthly base-load future prices on the last trading in month t for delivery in month T ($F_{t,T}$) and the spot average price in month t (S_t).

The overall model in 6.2 is significant at the 1% level with higher F-statistic and lower AIC value. Moreover the adjusted R^2 is 0.44, indicating that 44% of the variability of the relative electricity risk premium, is accounted for by those independent variables in the model. Although adjusted R^2 reduced compared to the general regression model, it still holds a high level of explanatory power. DW is close to 2, imply that there is no first-order serial correlation among the residuals.

residuals are uncorrelated if the value is approximately 2. A value close to 0 indicates strong positive correlation, while a value of 4 indicates strong negative correlation.

Coefficient	Variable	Base-load	Hypothesis
b0	Constant	-0.62(-3.50)***	
b1	Changes of Brent t	**-0.49(-1.90)***	+
b2	Auctions t	1.50(4.28)***	+
b3	Margin shock T	1.03(2.32)**	+
b4	Basis	-0.72(-3.12)***	-
b5	CV of spot price t	0.97(2.28)**	-/+
Adjusted R^2		0.44	
AIC		-34.4	
DW		1.75	
F-statistic		5.59	
Observations		63	

Table 6.2 Results of regression analysis (6.2) for ex-post month-ahead base-load relative forward risk premium based on future prices settled on the last trading day covering delivery month from January 2010 to March 2015(t-statistics in brackets). The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987)10. AIC represents the Akaike´s Information Criterion, and DW means the Durbin–Watson d statistic. *** (**,*) indicates significance at the 1% (5%, 10%) level11.

6.3 Results interpretations

This specific model suggests a more clear relationships between the proposed determinants and the risk premium. All the determinants listed in the model have significant coefficients, respectively, oil price changes (10% level), CESUR and OMIP actions (1% level), margin shock (5% level), basic (1% level), the coefficient of variance of spot prices (5% level) and the constant (1% level). Moreover, all determinants have the signs of coefficient as expected, except from oil price changes.

The significant positive influence of the regulated auctions (CESUR and OMIP call auctions) volume matched gives important insight into the impacts of regulated

[10] The Stata regress command includes a robust option for estimating heteroskedasticity and autocorrelation consistent (HAC) standard errors. With the robust option, the point estimates of the coefficients are exactly the same as in ordinary OLS, but the standard errors take into account issues concerning heterogeneity and lack of normality.

[11] The variation inflation factor (VIF) of the regression model is 1.88, indicating that there is no obvious multi-colinearity among independent variables.

instruments on market outcomes. The forward risk premium responds with the highest elasticity 1.50, implying that a 1% change of the regulated auctions volume matched induce a 1.5% change of electricity risk premium. It confirms the prediction that there is a strong interrelation between the resulting equilibrium price in these auctions and the price formation in the existing organized and non-organized markets (OMIP and OTC markets). The price inelastic demand of last resort suppliers in CESUR and OMIP auctions adds hedging pressure that could have promoted an upward bias in the forward prices.

Margin shock shows expected positive influence on relative electricity risk premium and is statistically significant. Similarly, the economic responsiveness is quite high with an average elasticity 1.03. Margin shocks, defined as the realized ratio of renewable energy generation to demand during the delivery month T, represents the misjudgment of future generation and demand conditions by market agents at trading month t. This significant influence confirms the hypothesis that markets agents have the adaptive expectation formation of future prices. Hence futures-spot bias cannot be explained by the risk assessments from the market agents only, it should include misjudgments of future generation and demand conditions by market agents causing the forecast error of risk premium.

The basis shows expected negative influence on risk premium. It is in agreement with the myopic approach of interpreting that markets agents forecast future spot prices based on adaptive expectation formation. With a perceived increasing of current spot prices, markets agents expect higher spot prices, and hence resulting in higher future prices. Based on the empirical test in Spanish markets, the future price increases 0.6 Euro/MWh to 1 Euro/MWh change in current spot price. Hence basis (difference of future prices and current spot prices) shows a negative influence on risk premium. It reflects the dynamics of spot markets.

The spot prices volatility (coefficient of variation) significantly influences the risk premium with a positive sign. This is in line with the Proposition 3.A. Positive influence supports the hypothesis that there is more hedging pressure from retailers who want to lock the prices compared to producers concerning variability of their profits. Thus increased spot prices volatility causes future prices to increase, and in turn results in an increasing risk premium. Moreover, a 1% increase of the spot price volatility causes an almost identical (0.97%) increase of relative risk premium.

The exception is the oil price changes which show an unexpected negative influence on electricity risk premium. The results suggest that 1% increase in oil prices leads to around 0.5% decrease in electricity risk premium. Possible explanation could be that increasing oil prices could induce increasing inflation. In fact, oil price changes account for more than 50% of the variance of Spanish inflation (Luis J. Álvarez., 2009). Producers are willing to sell in forward markets with lower forward prices with the fear of excessive demand reduction. However its influence is not as important as the influences of other determinants in terms of both statistical significance and magnitude of the coefficient (significant at the 10% level). Lastly the constant item shows a significantly negative coefficient, indicating that markets agents in Spain have a downward expectation of the electricity risk premium.

To summarize, the specific regression model suggests determinants significantly influencing the ex-post electricity risk premium, respectively, oil price changes, CESUR and OMIP actions, margin shock, basic, the coefficient of variance of spot prices. Particularly, risk premium responds as expected to the changes of those determinants. Oil price changes is the exception, however it can still be explained from another point of view. The regression results confirm and furthermore bring more insights into the corresponding propositions proposed in Chapter 5. It contributes to discovering the main drivers behind the future-spot price bias from a comprehensive perspective that covering behavioral effects, regulatory effects, shock effects and dynamic effects.

7 Conclusions and further research

7.1 Summary of the problem, the main findings

This thesis contributed to the literature analyzing the functioning of deregulated wholesale electricity markets. In particular, it focused on the empirical analysis of ex-post forward risk premium in the Spanish electricity market. It aimed to investigate the risk drivers behind the forward risk premium, and therefore to gain insights about forward price formation as well as the functioning of forward markets.

In this study, future prices for monthly base-load future contracts settled on the last trading day covering delivering time from January 2010 to March 2015 in OMIP, and monthly average spot prices from OMIE were used to calculate the ex-post forward risk premium. We proposed a comprehensive multifactor propositional framework so as to discover the determinants of forward risk premium. It included fundamental influences, behavioral effects, dynamic effects, market hedging, speculative activities and liquidity, regulatory instruments, and shock effects. In addition an econometric model based regression analysis was used to quantify the influence of these determinants on forward risk premium. To summarize, we found significant positive forward risk premium in the Spanish forward markets. The regression results suggested that market agents follow adaptive expectation formation rather than rational expectation. Moreover, the risk premium is positively influenced by regulated auctions, margin shocks, spot price volatility, and negatively influenced by basis.

7.2 Conclusions and implications

In this section, a deep analysis of the results is presented by referring to the research questions mentioned in Chapter 1.

What are the characteristics of ex-post forward risk premium?

It is found that ex-post forward risk premium changed sign and magnitude during the studying period. However on average the ex-post forward risk premium was positive with the magnitude of 9% (values taken for relative ex-post risk premium). Moreover the sign of the ex-post risk premium cannot be explained by risk considerations only, implying that market actors do not form rational expectations.

How the risk premium is related to fundamental measures of risks faced by market participates?

By testing the ex-post forward risk premium based on the Bessembinder and Lemmon equilibrium model, the results did not confirm their findings with opposite signs. Instead based on the regression model developed in this thesis, the variance of daily spot prices during the trading month positively influences the ex-post risk premium. It indicates that there is more hedging pressure from retailers who are risk aversion to spot price volatility. The spot price variance during trading month can be seen as the fundamental risk assessment by market participants who form adaptive price expectation.

How do supply and demand shocks affect risk assessments and market outcomes?

Increasing margin shocks leads to higher amount of renewable energy generation and lower demand, and therefore results in lower realized spot prices, higher risk premium. Due to the fact that market agents do not form rational expectations, margin shocks represents the misjudgment of future supply and demand conditions by market agents.

What is the effect of regulatory provisions on future market and forward risk premium?

CESUR and OMIP auction caused significant influence with highest coefficient 1.5 on the Spanish forward markets. In particular, these auctions increased forward prices and forward risk premium during the study period. Because of the inelastic demand of last resort suppliers and not sufficient physical producers participating in CESUR and OMIP auctions, the auctions increased hedging pressure for retailers that promoted an upward bias in the forward prices.

What is the effect of speculative and hedging activities on future-spot bias?

Bases on the regression results, there is no significant influence of open interest and volume on ex-post forward risk premium. After checking the colinearities between all the determinants (see Appendix F), it shows strong correlation between regulated auctions and open interest & volume. Specifically, regulated auctions is negatively correlated to volume and positively correlated to open interest. Hence it suggests that as the gradually decreasing regulated auctions during the study period, volume traded in Spanish forward markets was increasing, whilst the ex-post risk premium was decreasing. Since one of the main purposes for CESUR and OMIP call auctions is to foster the liquidity development in the forward markets, this negative correlation suggests that it to some extent helped develop the Spanish forward markets. However it only be concluded during the study period (from January 2010 to March 2015), for the reason that volume has been seen decreasing after the elimination of CESUR auctions. As for the open interest, it increases with a higher volume in auctions, which could imply that there is more hedging pressure from retailers who see the auction equilibrium price as price as reference of retail price and therefore, trade same contracts as those ones traded in CESUR auctions in OMIP market. Other explanation would be that there is more speculator activity; speculators could consider the CESUR auction as an opportunity to close the open positions in OMIP market.

What are the implications for the performance of electricity forward markets?

The average positive 10% relative ex-post forward risk premium indicates that future markets results are largely determined by retailers. In addition, the residual of the regression model does not confirm normal distribution, implying that there is still information not used by the market agents to form forward prices. Hence market inefficiency cannot be ruled out still.

Besides the determinants shown in the regression model, we did not find significant influence of natural gas forward risk premium and crude oil prices on risk premium. The reason lies in that gas-fired is not the price setting technology for spot price due to the substantially decreasing of CCGT generation and the increasing using of renewable energy sources. Hence influence of gas risk premium and oil price is not strong during this study. Lastly the basis is used as dynamic estimator of risk premium which captures the links between current spot prices and forward prices, in turn confirming that market agents follow adaptive price formation.

7.3 Future work

For the following study, it would be very interesting to study the daily future contracts as it contains the largest amount of data and liquidity. Moreover market agents have the most information and least forecast errors due to the shortest time maturity. Lastly, this multifactor framework can be used to compare different electricity markets (i.e. Spain, EEX, NordPool). It would contribute understanding the fundamental drivers of forward risk premium and therefore the forward price formation in a more general context.

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Appendix A- Seasonality analysis of demand with dummies variables

Regression analysis of monthly average demand from January 2010 to March 2015 with dummies. Q1, Q2, Q3 and Q4 represent respectively the first, the second, the third and the fourth quarter.

$$Demand_t = b1Q1_t + b1Q2_t + b3Q3_t + b4Q4_t + \varepsilon_t$$

STATA automatically dropped dummy Q2 to make it as a reference included in the constant. The regression formulated in STATA is as follows:

$$Demand_t = cons + b1Q1_t + b3Q3_t + b4Q4_t + \varepsilon_t$$

Panel A	**cons**	**b1**	**b3**	**b4**	**N**
Coefficient	27268.6*	3226.0*	1378.1*	998.1**	63
t-statistic	114.69	8.05	3.59	2.28	
Panel B	Adj.R^2	AIC	BIC	D-W	
	0.51	1077.081	1085.654	1.26	

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1 %(5%, 10%) level.

Hence

Q1 Demand=3226.0*1+1378.1*0+998.1*0+27268.6=3226.0+27268.6=30494.6

Q2 Demand=3226.0*0+1378.1*0+998.1*0+27268.6=0+27268.6=27268.6

Q3 Demand=3226.0*0+1378.1*1+998.1*0+27268.6=1378.1+27268.6=28646.7

Q4 Demand= 3226.0*0+1378.1*0+998.1*1+27268.6=998.1+27268.6=28266.7

So that the largest demand estimation is in Q1, then Q3, Q4, Q2 is the least one.

Appendix B- Seasonality analysis of volume and open interest with dummies variables

- Regression analysis of trading volume for monthly base-load forward contracts covering maturity time from January 2010 to March 2015 with dummies. Q1, Q3 and Q4 represent the first quarter, the third quarter and the fourth quarter. Q2 is included in constant. Volume includes OMIP continuous, OMIP call auction, OTC registered in OMIClear, OTC nonregistered.

$$Volume_{t,T} = cons + b1Q1 + b3Q3 + b4Q4 + \varepsilon_t$$

Panel A	**cons**	**b1**	**b3**	**b4**	**N**
Coefficient	28777***	-2012	4454***	8515***	63
t-statistic	26.33	-1.10	3.48	5.44	
Panel B	Adj.R^2	AIC	BIC	D-W	
	0.46	1245.9	1254.5	1.10	

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1 %(5%, 10%) level.

- Regression analysis of open interest on the last trading day for monthly base-load forward contracts covering maturity time from January 2010 to March 2015 with dummies. Q1, Q3 and Q4 represent the first quarter, the third quarter and the fourth quarter. Q2 is included in constant. Open interest includes OMIP continuous, OMIP call auction, OTC registered in OMIClear.

$$Open_{t,T} = cons + b1Q1 + b3Q3 + b4Q4 + \varepsilon_t$$

Panel A	**cons**	**b1**	**b3**	**b4**	**N**
Coefficient	1760	-92.8	-96.7	186.7	63
t-statistic	12.82	-0.45	-0.53	-0.87	
Panel B	Adj.R^2	AIC	BIC	D-W	
	0.04	984	993	1.00	

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1 %(5%, 10%) level

Appendix C-Seasonality analysis of absolute and relative risk premium with dummies variables

- Regression analysis of absolute ex-post month-ahead base-load forward risk premium with seasonal dummies covering maturity time from January 2010 to March 2015. Q1, Q3 and Q4 represent the first quarter, the third quarter and the fourth quarter. Q2 is included in constant.

$$F_{t,T} - S_T = cons + b1Q1 + b3Q3 + b4Q4 + \varepsilon_t$$

Panel A	**cons**	**b1**	**b3**	**b4**	**N**
Coefficient	2.36*	2.62	-2.36	-1.19	63
t-statistic	1.69	1.22	-1.39	-0.61	
Panel B	Adj.R^2	AIC	BIC	D-W	
	0.11	398.1758	406.7483	1.88	

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1 %(5%, 10%) level.

- Regression analysis of relative ex-post month-ahead base-load forward risk premium with seasonal dummies covering maturity time from January 2010 to March 2015. Q1, Q3 and Q4 represent the first quarter, the third quarter and the fourth quarter. Q2 is included in constant.

$$\frac{F_{t,T} - S_T}{S_T} = cons + b1Q1 + b3Q3 + b4Q4 + \varepsilon_t$$

Panel A	**cons**	**b1**	**b3**	**b4**	**N**
Coefficient	0.09	0.10	-0.09	-0.06	63
t-statistic	1.35	1.00	-1.26	-0.82	
Panel B	Adj.R^2	AIC	BIC	D-W	
	0.11	-9.41	-0.84	1.62	

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1 %(5%, 10%) level

Appendix D-Test B&L model with realized spot prices

Regression analysis between ex-post month-ahead base-load forward risk premium based on future prices settled on the last trading day and realized spot prices variation and skewness covering maturity time from January 2010 to March 2015.

$$F_{t,T} - S_T = b1 + b2Var(S_T) + b3Sknew(S_T) + \varepsilon_t$$

Panel A	**b1**	**b2**	**b3**	**N**
Coefficient	2.48	0.004	0.633	63
t-statistic	1.38	0.23	0.65	
Panel B	Adj.R^2	AIC	BIC	D-W
	0.02	402.5	408.9	1.88

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1%(5%, 10%) level

Appendix E- Regression analysis between future and current spot prices

Regression analysis between month-ahead base-load future prices settled on the last trading day covering delivery month from January 2010 to March 2015 and the monthly average spot prices in the trading month. Sources: OMIE, OMIP-OMIClear
$F_{t,T} = b1 + b2(S_t) + \varepsilon_t$

Panel A	**b1**	**b2**	**N**	
Coefficient	18.71***	0.63***	63	
t-statistic	5.51	8.67		
Panel B	Adj.R^2	AIC	BIC	D-W
	0.73	350.4	354.6	1.37

The t-statistics reported are based on heteroskedastic and autocorrelation consistent estimates of variances (Newey and West, 1987). N is the number of observations. Panel B reports the adjusted R^2, the Akaike´s Information Criterion (AIC), the Schwarz´s Bayesian information criteria (BIC), and the Durbin–Watson d statistic (D-W). *** (**,*) indicates significance at the 1%(5%, 10%) level.

Appendix F- Correlation matrix among variables

Correlation matrix between relative risk premium and all determinants shown in Equation 6.1.

	Ratio electricity RP	Ratio gas RP	Reserve margin	Skew spot price	Brent change	Auction	Margin shock	Volume	Basis	CV margin	CV spot price	Kurt spot price	Open interest
Relative electricity risk premium t	1.00												
Relative gas risk premium t	-0.15	1.00											
Reserve margin t	0.30	0.09	1.00										
Skewness of spot price t	-0.05	0.11	0.14	1.00									
Changes of Brent t	-0.05	-0.18	-0.10	-0.08	1.00								
Auctions t	0.12	-0.25	-0.35	-0.32	0.26	1.00							
Margin shock T	0.38	0.13	0.68	0.14	-0.07	-0.36	1.00						
Volume t	-0.19	0.19	0.18	0.24	-0.20	**-0.46**	0.18	1.00					
Basis	-0.03	0.05	0.34	0.23	-0.07	0.14	0.15	-0.09	1.00				
CV of margin t	0.12	0.09	0.00	-0.34	-0.06	0.02	0.19	-0.09	-0.26	1.00			
CV of spot price t	0.36	0.09	0.56	0.29	-0.06	-0.11	0.50	-0.06	0.71	0.00	1.00		
Kurtosis of spot price t	-0.02	-0.18	-0.15	-0.92	0.06	0.30	-0.17	-0.23	-0.12	0.18	-0.22	1.00	
Open interest t	0.04	-0.05	-0.38	-0.35	0.12	**0.56**	-0.37	-0.58	0.05	0.07	-0.10	0.31	1.00