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The development of the risk premium on one month futures in the Western European electricity markets

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PREFACE AND ACKNOWLEDGEMENTS

This thesis is about the premium on electricity futures. I have chosen to combine finance with a energy related topic since I am interested in the energy industry. Next to this the power markets are rather young and there are different areas in which a lot of research still can be performed. I would like to thank Mehtap Kilic and Ronald Huisman for their support and inspiration for this thesis.

ABSTRACT

Purpose: This thesis aims to investigate the development of the risk premium on base load electricity futures in the Western European region, consisting of the following markets: EEX (Germany), Powernext (France), APX (Netherlands) and Belpex (Belgium).

Methodology: We analyze the development of the observed – *ex post* – risk premium on monthly base load[1] futures in the period 2003-2009. This risk premium is qualified as the difference between the average futures price, in the month prior to delivery, and the average spot price in the delivery month. In our analysis we compare risk premiums in different sub periods and apply trend regressions to assess its development through time. We analyze the risk premium separately for each market.

Main findings: We find declining – non significant - risk premiums over the last three years at all markets. However over the entire study period risk premiums demonstrate a slight upward development. Besides this analysis of the risk premium level, we concentrate on its development in relation to zero. It appears that all markets show converging risk premiums to zero over the final three years. On top of that this convergence is highly significant. In addition we recognize a relation between declining volatility and lower risk premiums in the Western European markets. This is in contrast with the main outcome of the model of Bessembinder and Lemon (2002), in which they find a negative relation between variance and the risk premium.

Keywords:

Electricity, risk premium, futures, spot price, development, power market, Western European market, ex post risk premiums.

[1] Electricity can be bought for one price during all hours of the day. This is called the base load price. Another tariff is the price during peak hours (between 08:00 and 20:00). This peak load price lies above the base load price. Some exchanges offer off-peak load prices as well, which is for delivery of electricity in the off peak hours (between 20:00 and 08:00).

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CHAPTER 1 Introduction

Electricity has a specific feature with respect to other commodities as it is non storable. Although electricity can be stored in batteries, it is unfeasible for large quantities from an economic and technical point of view. As a consequence imbalances in demand and supply cannot be corrected via inventories. Therefore a situation of overcapacity or shortage in supply can overload the grid or result in a power shutdown.

Besides these physical consequences on the power grid, non storability involves pricing and trading of electricity at power markets. These markets faced a change over the last decade, as nearly all developed countries deregulated their electricity market to stimulate competition. As a result power exchanges came into existence, were producers, retailers and other players trade in electricity at the spot[2] and future contract[3] market. As electricity is non storable, a physical imbalance in demand and supply is reflected via the market. Spot prices extremely rise in the situation of more demand than supply, and on the other hand change in negative values in the case of oversupply. Therefore price increases of more than 100% are no exception. Next to this volatility, pricing of electricity cannot be and will not be based on simply holding the commodity in an inventory as it is non storable. This makes the electricity market very challenging, inducing high risks for the players involved.

Players involved in this volatile spot market can try to hedge their risk with electricity derivatives, like future contracts. These futures are used to fix the delivery price over a predefined standard period. In most electricity markets they are available for the period of a month, quarter, half year and full year. Example: if a retailer buys a future for September 2010 with a rate of €35/MWh, a retailer can buy electricity in the entire month. Due to this a retailer is protected against spot prices above €35. However if the spot price ends below €35/MWh in this month, the retailer could have bought the electricity at the spot market for a lower rate. As a future is bought prior to the delivery period, its price will probably differ from the spot price at the actual moment of delivery. This difference is further referred to as the risk premium and a positive observed risk premium implies to the situation were the price for a future ends above the spot price in the period of delivery. In contrast, a negative risk premium can be observed when the future ends below the actual spot price. When there would be no price difference between the future and the actual spot price, then a futures price would be a perfect indicator of the spot price in that period.

[2] In the spot market electricity for next day delivery is traded. Another description for these markets is the day-ahead market. Some markets offer intra-day trading as well now. In this thesis we focus on the spot market, in combination with the futures market only.

[3] Though there are differences between forward and future contracts, the general application of the product is identical: it fixes the price of an underlying product in the future. We will refer to future contracts, or simply called futures, in this thesis as these are the one investigated. In Chapter 2 (Literature review), we refer to forward or future contracts according to the practice of the author(s).

In this thesis we analyze the development of the risk premium in the Western European market, which exists of the EEX (Germany), the Powernext (France), the APX (Netherlands) and the Belpex (Belgium)[4]. In addition our focus is on base load power prices, which is a tariff for delivery over the entire day.

Several developments triggered us to perform this research as we nowadays find a converging trend to one large market in Europe: adjacent markets – countries[5] - are stimulated to integrate their markets and intensify cross-border delivery. This stimulates competition and reduces the price risk on these markets, as there will be fewer imbalances in demand and supply. In addition time series of the spot prices indicate less frequent extreme price peaks. Another development is that market knowledge and experience of the different players involved in these markets has been growing. Therefore we are interested in whether the level of the risk premium is undergoing a change as well.

This paper is organized as follows. Chapter 2 summarizes the literature regarding the integration of the electricity markets, the relation between spot and futures prices and the research to the risk premium so far. In chapter 3 a short overview of the four markets is given. Chapter 4 describes our methodology, followed by an analysis of the data in section 5. Based on this analysis we construct an expectation regarding the development of the risk premium in section 6. In chapter 7 its development is assessed with the results of our analysis. Chapter 8 concludes.

[4] EEX: Energy Exchange. APX: Amsterdam Power Exchange. Belpex: Belgian Power Exchange.
[5] In Europe each country has one market. This is in contrasts with for instance the U.S., were due to the large size of the country more markets are active.

CHAPTER 2 Literature review

2.1 Reform throughout the electricity markets

Several electricity markets worldwide have been facing a structural change over the last years. These changes are in the direction of liberalization and driven by the desire to end monopoly positions to decrease the prices paid by end-users. In relation to this Jamasb and Pollit (*2005)* investigated different market transformations and signalled an essential role for the government, which according to them has to initiate the restructuring. Next to this the authors mention that decoupling of generation and transmission activities is key to a successful liberalization. This will guarantee free access to the transmission network and avoids misuse of the powerful position of incumbent players. Another crucial factor for a successful transformation is the creation of effective wholesale and retail markets, with a pool that facilitates trading for the spot and futures market (Mork, *2000*). On top of that the electricity market has to offer low entry barriers and clear and transparent regulations.

The US and Chile were the first to deregulate, respectively in 1978 and 1984. However in Europe the UK was the first country that restructured its electricity market in 1990 with their Electricty Act (Mork, *2000*). After the state owned Central Electricity Generating Board was split into three generators and a transmission company, they created a pool in order to stimulate a competitive setting between the generators. Therefore all generators were obliged to sell to the pool and consumer demand was met from there. Nevertheless as two of these generators owned the conventional price setting plants, they were still able to set the price. After regulatory pressure the market slowly developed into a competitive market and after ten years the market was completely changed, with all consumers free to choose their electricity supplier (Al-Sunaidy and Green, *2006*).

Shortly after the UK, Norway began its transformation as well. The country passed the Norwegian Electricity Act in 1991, which allowed a progressive number of consumers to select their electricity supplier. Two years later Norway operated the first official spot market for electricity, while trading in futures and forwards started in 1996. It was this power exchange that grew into the Nord Pool market, which now includes Finland, Sweden, Denmark and a part of Germany (Mork, *2000*). More countries followed; the APX opened in 1999, Powernext in 2001 and the EEX in 2002.

In addition to individual governments that stimulated the market transformation, EU countries were facing regulation changes as well. These regulation are a results of the EU's objective to create one single European electricity market, by deregulation and ending monopolies and inefficiencies. In addition cross-border interconnections have to improve on the long term. One of the desired results is lower prices for end-users acquired by competition, while it gives the EU a competitive position regarding electricity for the future[6]. In line with their objective the EU launched its first draft of *Directive*[7] *96/92*[8] in 1991. This

[6] European Commission Report, 1999

[7] A directive is a statutory law of the EU, which requires member states to achieve a particular result, without dictating the means of coming to that result.

directive focused on deregulation and opening of the different markets. However the market transformation described in this directive was aimed at a low pace and therefore accelerated by *Directive 2003/54*[9]. This second directive worked with short-term deadlines and focused on retailers and required independent regulators. It stated that all consumers had to be free to choose their own supplier from the 1st of July 2007.

Meeus and Beltmans (*2007*) investigated this integration of the European electricity market. They conclude that a lack of focus on the market's regulation, made the country's individual regulators initiate the integration of the EU market. Next to this Pereira da Silva and Saores (2008) assessed the EU market integration as well. They performed an investigation to the spot price convergence of the different markets between 2002 and 2004. Their paper shows that price differences have deceased, which might be an indicator for market integration. However the authors conclude that the correlation level between the different European markets is low. In addition they conclude that just 8-10% of national consumption originates from cross-border trading. It appears that the greatest barrier for trade is the lack of installed cross-country capacity.

2.2 Relation between spot and futures prices

This transformation process has resulted in the origination of several power exchanges, which offer the possibility to trade on spot and derivative markets. Prices on these exchanges expressed highly volatile patterns over the first decade and the price line in figure 1 is a clear example. It represents the spot[10] price for base load electricity on the EEX. Similar volatile patterns can be found among other spot markets.

The key driver behind this volatility is the non storability (Bessembinder and Lemmon, *2002*). As a discrepancy between demand and supply on the spot market cannot be controlled via an inventory, like in the situation of most storable commodities[11]. Next to this it is difficult to buy power from distant regions, as electricity cannot be endlessly transported over large distances. Another crucial condition for effective transport is adequate grid capacity, which is not always available as well. As a result imbalances can lead to extreme high prices, or even negative electricity prices[12]. In addition non storability is also reflected in substantial divergence of day and night prices (for example Longstaff and Wang, *2004*) and seasonal price differences (for example Pietz, *2010*). This latter effect can be recognized in higher summer and winter prices at markets with strong temperature differences between the seasons, due to a higher power demand for climate control.

Volatility makes it hard to predict future power prices and leads to a high price risk on the market. Hence this volatility is a crucial price driver for risk hedging derivatives, like futures, or the price of

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[8] Directive 96/92/EC

[9] Directive 2003/54/EC

[10] In general the day-ahead is referred to as the spot market. Electricity is traded today for delivery tomorrow.

[11] It is true that fuel for the generation of electricity can be stored (gas, oil, coal, water reservoirs). However it lacks the swift conversion possibility in the case of an (unanticipated) mismatch in demand and supply.

[12] Due to specific regulation at individual country level, a generator has to forecast the electricity demand from its customers within a certain range, to prevent overburdening of the grid. When demand is lower than anticipated, the grid can get overloaded. In that situation a generator has to pay a fine for the surplus amount of electricity on the grid, which can lead to negative prices.

physical storage in the case of other commodities (Pindyck, *2001*). In general the literature describes two theories for the relation between spot and futures prices in commodity markets. These both theories

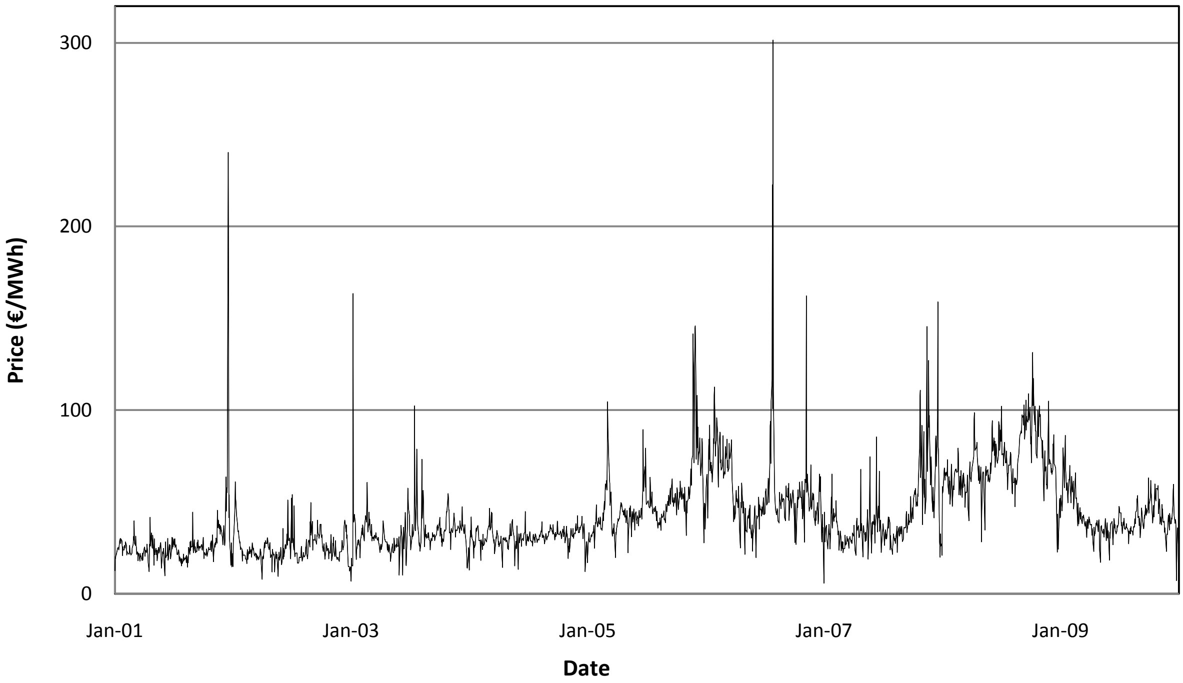

Figure 1. Daily closing prices of German base load electricity at the EEX. Prices in euro's per megawatt hour.

can be found in the often cited paper by Fama and French (*1987*). The first is known as the theory of storage and based on the risk-free position of holding the commodity in an inventory until the moment of delivery. In this theory are therefore reflected the cost of storage, foregone interest and a convenience yield of holding the commodity. Moreover it is assumed that there are no arbitrage possibilities between the market of spot and futures. However electricity's non storability implies that this first theory can be excluded as a method to describe the relation between spot and futures prices. Then there is a second theory, which is not based on the risk-free position of holding a certain commodity in inventory. It can be described as the risk premium theory. This theory aims on the expected spot price of the commodity at the maturity date. On top of that a certain risk premium is added to determine the futures price. This theory can be found in formula (1,) were the futures price for period T, at the current time t, is formed by the expected spot price in T at the current time t, plus a risk premium (π). One has to bear in mind though that both theories are not mutually exclusive, since the convenience yield is based on expectations of the expected spot price.

$$(1) \qquad F(T)_t = E_t\,[S(T)] + \pi(T)$$

As this latter theory reflects the expected spot price plus a risk premium, it is the most appropriate for assessing the relation between spot and futures prices. According to Bessembinder (*1992*) this risk premium is driven by two determinants. The first one is the need for hedging, as traders have the desire to reduce their risk. An example: as producers want to hedge their price on the long term, then a supply of long term contracts results. If on the other hand consumers want to hedge their short time demand, there forms an excess demand for short term contracts. This leads to a positive premium on short term contracts and a negative premium on the long run. In contrast with the need for hedging Bessembinder (*1992*) also argues that premiums can be seen as non diversifiable risk, under the assumption that portfolios of futures can be freely diversified. By regarding a future as an asset, premiums differ due to their relation with the market portfolio. See Botterud et al. (*2009*) for a broader discussion on both determinants

If futures prices are perfect indicators for expected spot prices, the premium would be zero. Therefore the risk premium theory has always been an important research topic and the greater part of financial electricity literature is based on it. As mentioned earlier, Fama and French (*1987*) wrote a leading paper regarding to the spot and futures relation. They found no strong consistent evidence of a non-zero risk premium in their research on different commodities[13].

2.3 Empirical results on the risk premium in electricity markets

From the literature covering the electricity risk premium we can find strong proof for the existence of non zero risk premiums. A leading research rated on the number of references is performed by Bessembinder and Lemmon (*2002*). They investigated premiums on forward prices[14] at the day-ahead market in the US between 1997 and 2002. For this the authors created an equilibrium model, based on the underlying predictions that forward prices are known and market players can forecast demand on a one day basis. They based their model on forwards only, since trading in futures was at a low level in 2002. In addition an important assumption was made that there are no outside speculators. Therefore trading is exclusively done by producers and suppliers. The model implies that forward prices are biased predictors of future spot prices. An important finding is that forward premiums on expected spot prices decrease with anticipated variance of the current spot prices and increase with anticipated skewness. Next to this Bessembinder and Lemmon (*2002*) found a positive risk premium on forwards during the summer on the PJM[15] and CALPX[16] markets.

While the research of Bessembinder and Lemon (*2002*) is based on a specific equilibrium model (further referred to as the B-L model), Longstaff and Wang (*2004*) focused on the premium on day-ahead forward prices as well. They tested the outcomes of the B-L model and discovered that during peak hours forward premiums are the highest on the PJM market. As support for the conclusion of Bessembinder and Lemon (*2002*), they found empirical evidence that forward premiums for electricity are negatively related to spot price variance and positively related to price skewness. One has to bear in mind that, similar to Bessembinder and Lemon (*2002*), they based their forward period on the day-ahead market. In line with

[13] For other studies regarding the spot-futures relation on storable commodities see for example Considine and Larson (*2001*) or Wei and Zhu (*2006*).
[14] As the forward period they apply a one day period by comparing real time spot and day ahead ‘forward’ prices.
[15] PJM stands for the electricity market of Pennsylvania, Jersey and Maryland
[16] CALPX stands for the Californian Power Exchange

this Ullrich (*2007*) constructed his research on the same model, although with a constraint on capacity. He concluded that the forward risk premium, the difference between the forward price and the expected spot price, depends on the level of the expected spot price in relation to the fixed retail price.

Until this point we can characterize the discussed papers as according to the *ex ante* research method. This method constructs the risk premium with expected future spot prices, as in formula (1). However there are also other papers that focus directly on the analysis of the observed risk premium, which results from the realized spot and futures price over the specific period and is known as the *ex post* method.

In line with this *ex post* method Shawky et. al (*2003*) performed empirical research on premiums on half year forward contracts at the California-Oregon border. They found significant non-zero premiums, while Lucia and Torró (*2008*) presented on average positive risk premiums at contracts with a short term to maturity. These authors based their research on ten years of data from the Nord Pool market and concluded that premiums were found to be the highest during summer periods. Another paper that focused on the Nord Pool market is written by Botterud et. al. (*2009*). They analyzed 11 years (1996-2006) of data from spot and futures prices, based on a weekly period. Futures prices tend to be higher than spot prices, although it depends on the season and the amount of water stored in the hydro reservoirs. Next to this Furio and Meneu (*2008*) investigated the Spanish electricity market and found both *ex ante* as *ex post* non-zero risk premiums on futures with a maturity of a month.

Several papers investigated the risk premium in the Western European markets. Diko et. al (*2006)* focused on Germany, France and the Netherlands for risk premiums on the day-ahead markets. Similar to Bessembinder and Lemmon (*2002*) and other papers, they found non-zero risk premiums. In addition Wilkens and Wimschulte (*2008*) investigated the premium on EEX's monthly forward contracts in the period 2002-2003. With a one factor model they found a on average positive risk premium, which shows strong variability. Another paper on EEX futures is written by Pietz (*2009*). He demonstrated positive risk premiums on one month futures, which decrease with time to maturity. On top of that evidence for seasonality was found, with negative risk premiums in summer. This is in contrast with research by Botterud et al. (*2009*) for instance. Another paper of Bunn and Gianfreda (2010) showed a perfect forecast ability on the Dutch market, which implies a zero risk premium and researched the European market integration from 2000 till 2005.

All this research on risk premiums is constructed in the rather young and developing electricity markets, with a maximum data horizon of eleven years. However all papers prove the existence of non-zero risk premiums on futures and forwards. This thesis contributes to the literature by its investigation to the development of the risk premiums on futures in the Western European markets over the last seven years. It shows the volatile pattern of the monthly risk premiums. Next to this it demonstrates that the average level of the *ex post* risk premium declines at all markets from 2007 to 2009. In addition to this decline at the absolute level, this thesis shows strong significant results regarding the development of the premium in relation to zero. In 2008 and 2009 all four markets show converging risk premiums in relation to zero, which implies that futures become more accurate forecasters of future spot prices. Moreover these developments run parallel to the convergence of prices and volatility across the four spot markets. Besides convergence we demonstrate a declining volatility of spot prices and risk premiums.

CHAPTER 3 The Western European electricity markets

In this thesis the development of the risk premium on one month futures is analyzed for the German, French, Dutch and Belgian market. These markets are also known as the Western European market. This section exists of a description of the markets of these countries and the current state of the underlying integration.

3.1 Description of the four markets[17]

The German based EEX is the largest energy exchange in continental Europe and offers spot market, intraday and derivatives trading. In the field of spot power trading the EEX has formed a joint venture with the Powernext (France), which is called EPEX and based in Paris. This joint venture operates the spot market power trading for Germany, France, Switzerland and Austria. Regarding electricity derivatives the EEX started a cooperation with the Powernext in 2008 (EPD). Futures for monthly, quarterly and yearly periods are traded at the EEX for Germany, Austria and France. This joint venture is based in Germany. Another cooperation with Powernext is the European Commodity Clearing, which is responsible for the clearing of all spot and derivatives transactions.

The second exchange is the Powernext (France), which started with power trading on the day-ahead market in 2001. As stated above, the Powernext has formed a joint venture with the EEX regarding trading at the spot and derivative market. Therefore France spot power is bought via the EPEX while clearing and settlement is provided in cooperation with the EEX as well. Next to this Powernext is a 10% shareholder of Belpex, the Belgian power exchange. Although French and German spot electricity is traded via the EPEX, we will refer to the EEX and the Powernext in this thesis, as prices are quoted separately at the EPEX.

The Anglo-Dutch APX is formed in 1999 as a platform for trading in gas and electricity for the UK and the Netherlands. At the APX trading in electricity is possible in the day-ahead spot market, while Dutch futures are traded at the European Energy Derivatives Exchange (Endex). Since December 2008 this exchange belongs to the APX group. This platform also offers trading in electricity futures for the UK and Belgian market. Moreover APX is a 10% shareholder of Belpex as well.

The last exchange is the Belpex, which exists from 2006 and offers day-ahead spot trading in electricity on the Belgian hub. This exchange is owned for 10% each by the APX, the Powernext, TenneT (Dutch transmission system operator) and RTE (French transmission system operator). The other remaining shares are owned by the Belgian transmission system operator. Also futures for Belgium are traded on the Endex, similar to the Dutch power futures. Besides its function as an exchange for spot prices, Belpex also facilitates the market coupling between Belgium, France and the Netherlands. This contributes to the integration of the Western European electricity markets. Although Dutch and Belgian futures are both traded at the same platform, the Endex, we will refer to APX and Belpex regarding futures as well.

[17] Information for this chapter is extracted from websites of the EEX, the Powernext, APX and the Belpex.

3.2 Integration of the markets

As we shortly described above, Belgium has an important function in coupling of the Dutch and French electricity markets; it facilitates simultaneously the trading of power and the transport capacity. The main purpose of this coupling is to maximize the total economic surplus of all participants as the highest purchase and the lowest sale orders are matched across all three markets. The results of this matching depends on the available transfer capacity. Thus in a situation of enough capacity prices convert and the implicit cost of transmission would be null[18]. In 2009 the day-ahead price was equal in all three markets of 56,8% of the time, in comparison with 62,1% and 68,1% in 2007 and 2008 respectively[19].

There is no similar market coupling between the Dutch and the German market. Between these markets transmission capacity is sold by the regulators to the market players in the form of an auction. This results in a capacity distribution which is unrelated to price developments on the APX and EEX. Therefore a report by the Dutch Energy Chamber[20] emphasizes on this non optimal capacity utilization between Germany and the Netherlands. However the report expects a market coupling between both markets to commence in 2010.

In addition to this market coupling the EEX and the Powernext have their joint venture on spot market trading, which stimulates the integration between the German and French markets. According to Haas et al. (*2008*) Austria, Germany, France and Switzerland form one joint electricity market with one market price. They describe this in their report for the IAEE[21]. However the spot prices are not equal on these markets.

This German-French relation, together with the market coupling between Belgium, France and the Netherlands, gives solid reasons for a integration of the Western European markets. However Pereira da Silva and Soares (*2008*) emphasize on the low interconnection capacity between the four markets. With a low transmission capacity between different countries, markets remain separated when the transport capacity is fully used. Next to this they mention that the concentration among the electricity generators is still high, especially in Belgium and France where the largest players hold respectively 80% and 87% of the capacity[22].

[18] Trilateral Market Coupling (2006)
[19] Belgian Commission for regulation of gas and Electricity (2010)
[20] De Nederlandse Energiemarkten in 2009 (2009)
[21] International Association of Energy Economics
[22] Eurostat Database, market share of the largest generator in the electricity market for 2008

CHAPTER 4 Methodology

In our analysis of the development of the base load risk premiums we will focus on monthly futures that are traded at the EEX, Powernext, APX and Belpex. Monthly futures fix the price for delivery of a full calendar month and can be traded until the last trading day of its preceding month. Due to the low quantity of available data the quarter, semi-year and full-year futures are excluded. We will apply the *ex post* method and focus on the observed risk premiums over a period of 7 years, which runs from January 2003 to December 2009 and consist of 84 months in total. These 84 observed risk premiums will be calculated for each electricity exchange[23] with formula (2).

$$(2) \qquad \pi\,(T_t) = \frac{F(T)_{t-1} - S(T)_t}{F(T)_{t-1}}$$

The observed risk premium, $\pi\,(T_t)$, is calculated on monthly futures. T represents a specific month, in which the electricity is delivered. January 2003 (T_1) forms the first month to determine the risk premium on, February 2003 (T_2) the second month, and so on. $F(T)_{t-1}$ reflects the average of the daily closing future prices of base load electricity in the month prior to delivery, period $t-1$. Next the risk premium is obtained by subtracting the average daily closing spot price of base load electricity in the month of delivery, $S(T)_t$, from the average future price in the month prior to delivery $F(T)_{t-1}$. As the formula above shows, the risk premium is expressed as a percentage of the average future price of the month prior to delivery. This method is applied since electricity prices show a volatile pattern during our period of investigation and the average spot price increases over the 2003-2009 period. Therefore absolute premiums may lead to a wrong interpretation of the risk premium development.

We will use the average futures price in the month prior to delivery, $F(T)_{t-1}$, as trading volumes are the highest in the last month to maturity[24]. A second motive for using the average future price over the entire prior month is that risk premiums change with respect to maturity (see for example Shawky et al., *2003*). Therefore it is not optimal to use for example the first day in the prior month to acquire the future price.

To test the presence of non-zero risk premiums we will perform regressions on the monthly risk premiums of each market. First regression (A) is applied, where μ is the value of the mean observed premium over the study period 2003-2009. With this regression (A) the following hypothesis is tested: H_0: $\mu = 0$ against H_1: $\mu \neq 0$. This hypothesis is also applied in the work of Furio and Meneu (2010).
In addition smaller time frames[25] are applied as well to identify potential common or specific trends among the markets.

[23] As the trading in Belgian Electricity futures was available from September 2004, 63 contracts passed till the end of 2009. For the France market Bloomberg offers futures data from March 2005 and therefore 59 contracts passed.
[24] Research by Pietz (*2009*) to risk premiums on EEX futures in a period from 2002 to 2008, shows that one month futures are most traded in the last month to delivery.
[25] We will split the period into the following sub-periods: 2003-2005. 2006-2007 and 2008-2009.

(A) $$\pi\,(T) = \mu + \varepsilon_t$$

Results of regression (A) might results in the detection of potential trends in the development of the risk premium. Therefore we will intensify the analysis of potential trends with a trend regression (B). In this second regression monthly risk premiums are regressed against *T*, where *T* as number represents the 84 months in our study period. It starts with *T*=1 and the risk premium in January 2003, *T*=2 stands for February 2003, and so until *T*=84, which represents December 2009. With this linear time trend regression the slope of coefficient β is estimated. In this way a positive (negative) β indicates on average rising (declining) monthly risk premiums. In addition to a trend line analysis over 84 months, we can limit regression (B) to a specific period.

(B) $$\pi\,(T)_{\boldsymbol{t}} = \alpha + \beta T_t + \varepsilon_t$$

CHAPTER 5 Data analysis

Our study period is from 2003 to 2009 and all data is extracted from Bloomberg, with exception of Belgian spot prices. The Belpex has been active since November 2006 and prior to this moment trading was possible via the Belgian Power Index[26]. Therefore spot prices before 2006 are provided by Electrabel, while the Belpex website supplies spot prices from 2006. In addition all prices used in this research are daily closing prices. Futures are traded during weekdays and prices are not quoted in weekends, however spot prices are quoted during the entire week. Although base and peak load prices are strongly correlated, Karatsaki and Bunn (*2005*) show different risk premiums on base and peak load futures. Therefore we emphasize on the fact that this research is based on base load prices only.

5.1. Spot prices

First we will analyze the development of the spot prices from 2003 to 2009. Figures 2.A till 2.D show the time series of the daily base load spot prices for each market for the entire study period; EEX(*2.A*), Powernext(*2.B*), APX(*2.C*) and Belpex(*2.D*). It is obvious that all graphs confirm the volatile and capricious behavior of electricity prices. Also notice the high peaks at the Powernext and the APX above €600 per MWh.

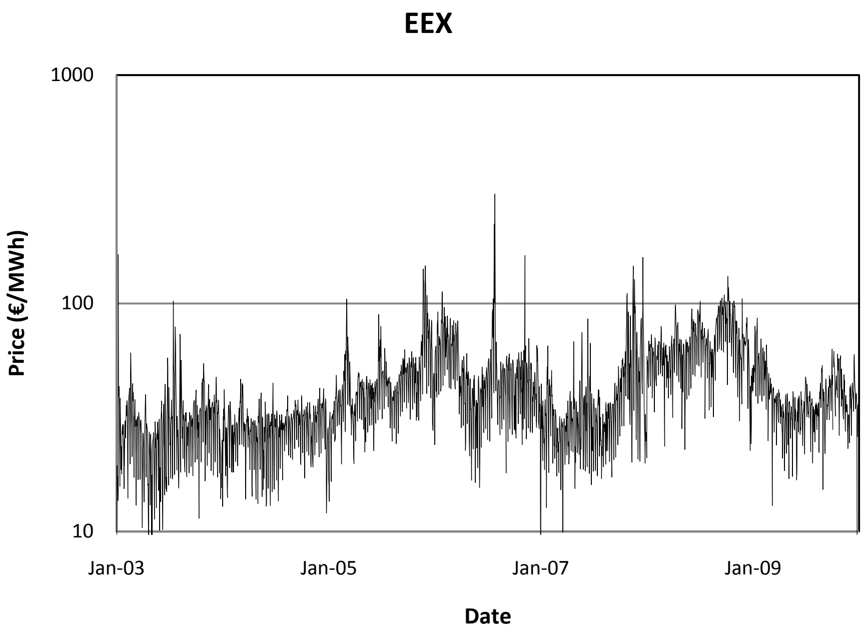

Figure 2.A. Time series of the daily closing price of German base load electricity at the EEX. Prices in euro's per megawatt hour. Period 2003-2009.

[26] This index was owned by Electrabel, who set the prices their self. There was no competition.

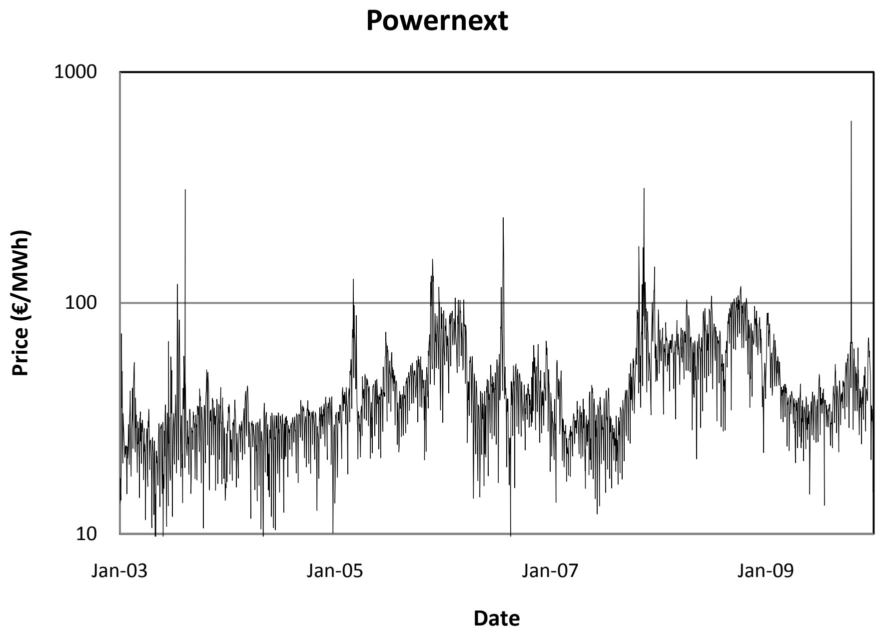

Figure 2.B. Time series of the daily closing price of French base load electricity at the Powernext. Prices in euro's per megawatt hour. Period 2003-2009.

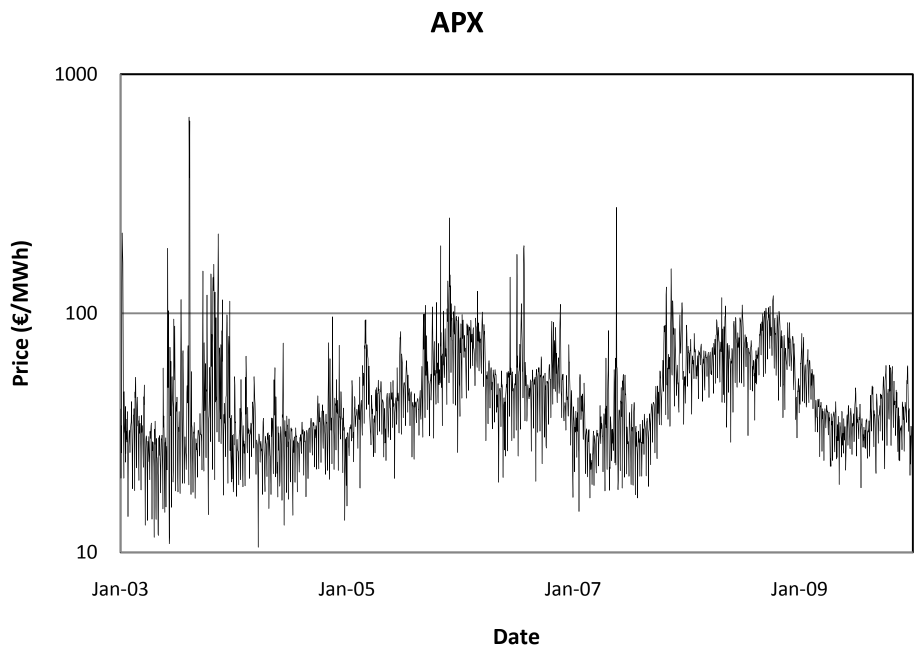

Figure 2.C. Time series of the daily closing price of Dutch base load electricity at the APX. Prices in euro's per megawatt hour. Period 2003-2009.

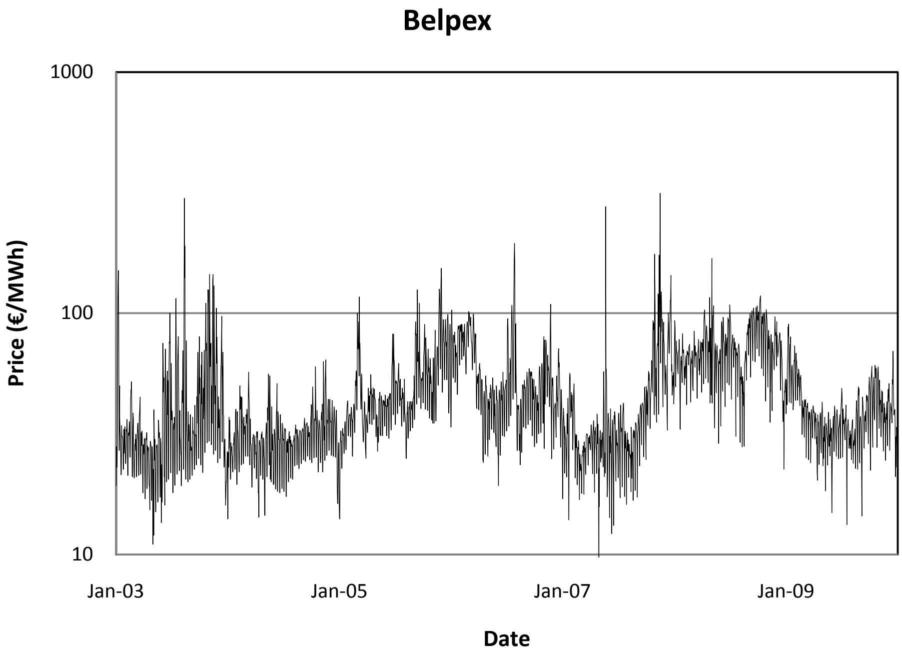

Figure 2.D. Time series of the daily closing price of Belgian base load electricity at the Belpex. Prices in euro's per megawatt hour. Period 2003-2009.

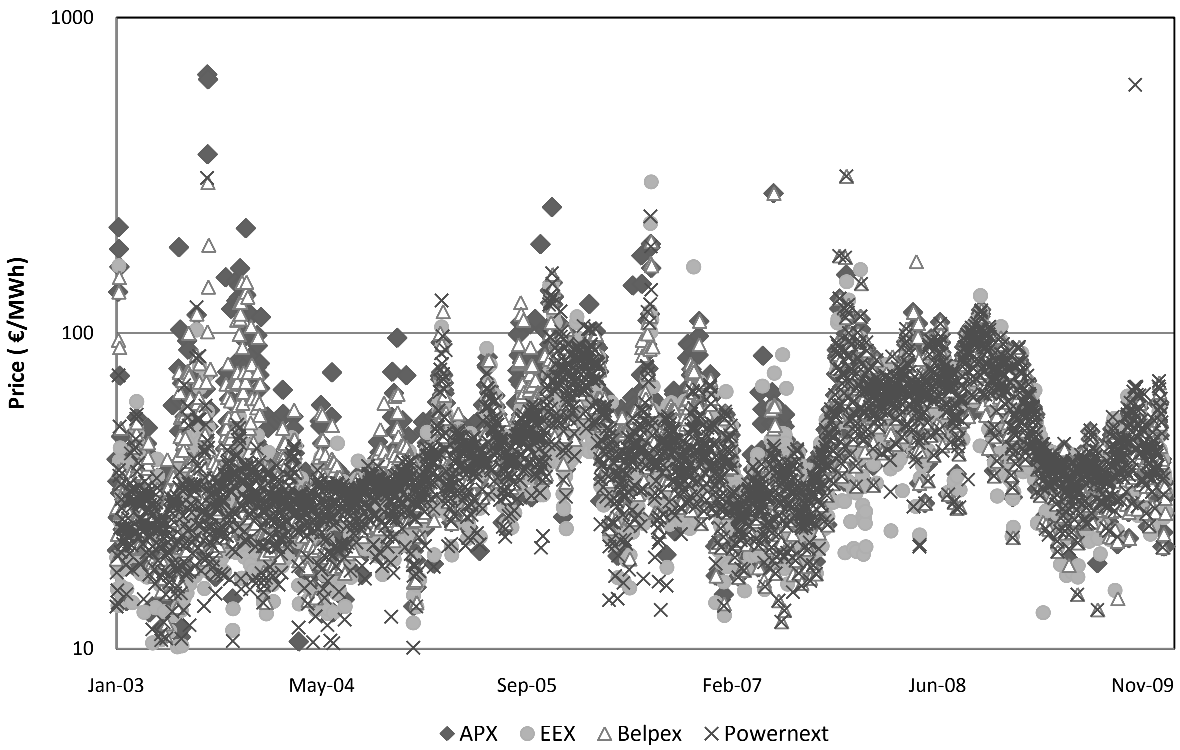

Figure 3. Scatter plot of the daily closing base load electricity prices at the EEX, the Powernext, the APX and the Belpex. Period 2003-2009.

To assess the development of the joint price risk for all markets on a visual basis, figure 3 combines figures 2.A till 2.D in a scatter plot. This figure consists of more than 10,000 observations and although the graph is not very detailed due to the high number of observations it displays a clear bandwidth were the greater part of the spot prices stay within. However there are frequent outliers above €100 per MWh, with even three observations above €600. From June 2008 the figure shows less extreme outliers and prices seem to stay within the general bandwidth. Overall this pattern suggests a declining volatility at the four markets in the final years. On the other hand there remains one remarkable high French price on the 18th of October 2009 of €612.77.

Next we will continue our analysis of the spot prices in table 1. It shows descriptive spot price statistics for the four different markets over the entire period. Over the entire period APX shows the highest spot price with an average of €48.49. However the lowest average base spot price applies to the EEX, €42.49. Also the standard deviations of the four markets show diversity, with a €10 difference between the APX and the EEX. In line with the extreme peaks for the Powernext and the APX, the skewness levels of both exchanges are much higher in relation to the Belpex and the EEX. Overall the EEX can be regarded as the market with stable prices and the lowest average price. Its maximum spot price was €301.54, versus €660.34 for the APX.

Then in table 2 the period is divided into three sub periods to identify possible trends in the development of the mean, standard deviation and skewness of the spot prices. These sub periods are 2003-2005, 2006-2007 and 2008-2009. The mean prices at the four markets show a converging pattern towards €55. Probably the Belgian market coupling will have had its influence on this convergence of the spot prices, as prices were equal in the three countries for 56,8% of the time. Electricity at the EEX and the Powernext experienced the strongest price increases over the three periods. Both prices rose with more than 50%.

Table 1. Descriptive statistics of the daily closing base load spot prices for the study period 2003-2009. Prices are quoted in €/MWh.

	2003-2009				
	EEX	POW	APX	BEL	Average
Mean	42.49	43.77	48.49	46.71	45.37
Median	37.28	37.09	41.26	39.50	38.78
Maximum	301.54	612.77	660.34	314.27	472.23
Minimum	-35.57	6.88	10.52	6.16	-3.00
Std. Dev.	20.83	25.75	30.29	24.75	25.41
Std. Dev.(%)	49.03%	58.82%	62.48%	52.98%	56.00%
Skewness	2.25	6.13	7.68	2.48	4.63
Kurtosis	16.99	107.12	131.48	17.66	68.316

Table 2. Descriptive statistics of the daily closing base load spot prices over different sub-periods; 2003-2005, 2006-2007, 2008-2009. Prices are quoted in €/MWh.

	2003-2005					**2006-2007**					**2008-2009**				
	EEX	POW	APX	BEL	Average	EEX	POW	APX	BEL	Average	EEX	POW	APX	BEL	Average
Mean	34.67	34.69	43.45	40.17	38.25	44.39	45.12	49.95	48.20	46.91	52.38	56.11	54.60	55.08	54.54
Median	31.97	31.14	34.69	34.50	33.08	39.86	38.62	46.03	42.00	41.63	48.54	53.22	51.88	51.54	51.29
Maximum	163.46	310.37	660.34	300.00	358.54	301.54	314.27	277.41	314.27	301.87	131.40	612.77	118.59	168.53	257.82
Minimum	31.20	67.87	10.52	11.00	30.15	58.00	95.13	14.83	61.60	57.39	-35.57	13.28	18.63	13.28	2.40
Std. Dev.	15.75	18.43	37.47	22.77	23.60	23.20	25.99	24.45	27.36	25.25	20.43	29.34	20.75	21.97	23.12
Std. Dev.(%)	45.42%	53.11%	86.22%	56.69%	61.71%	52.27%	57.61%	48.94%	56.75%	53.82%	39.01%	52.29%	38.00%	39.89%	42.39%
Skewness	2.79	4.92	9.19	3.29	5.05	3.49	3.33	2.60	3.23	3.16	0.52	95.62	0.53	0.66	23.91
Kurtosis	17.58	54.89	133.45	23.71	57.41	29.66	24.91	17.37	23.87	23.95	34.20	179.53	25.08	32.27	67.77

The standard deviations demonstrate a strong converging pattern as well, both absolute as relative. Over the first period the standard deviations clearly vary, from €18 for the Powernext up to €37 for the APX. Over the second and third period a clear converging trend can be identified among the EEX, the APX and the Belpex. All three levels converge to €21 in the 2008-2009 period. Only Powernext forms an exception, which is caused by the single high price of €612.77 in October 2009. However without this single outlier, the standard deviation for the Powernext would be €20.82 and on thus the same level as the other three markets. Such an identical relation exists between the two outliers of the APX in 2003 and its high volatility over the first period[27]. In addition we can conclude that generally the second sub period can be characterized as the most volatile period.

The average standard deviation, as a percentage of the spot prices, of the four markets declines from 62% in the first period, towards 54% in the second period. One has to bear in mind that the high average volatility in this first period is caused by the APX peaks. On an individual basis the EEX, Powernext and Belpex even increase in relative volatility over the first to the second period. The last period of 2008-2009 demonstrates a volatility of 42% for the Western European markets, while all volatility levels decrease. The volatility at the EEX shrinks from 45% in the first period to 39% in 2008-2009; a decrease, versus an increase at the absolute level. Also for the Powernext the relative volatility decreases from 59% in 2003-2005 to 52% in the last period, this includes the high price in October 2009.

Over all three periods the absolute volatility level for the German and French market has risen, which is in contrast with a decrease in Belgium and the Netherlands. However the volatility in terms of percentage declined and converged in all markets

Besides an analysis of the mean and volatility pirces, we will briefly focus on the skewness level as Bessembinder and Lemmon (2003) find a positive relation between skewness and the risk premium. Among the four markets a strong converging trend for the EEX, APX and Belpex can be recognized as well. Skewness levels differ between 3 or 4 in the first two periods, followed by a decline and convergence in 2008-2009 towards 0.6. It is only Powernext that forms an exception due to the high price in the final period. High prices at the APX and Powernext are also expressed via high Kurtosis levels; in the 2003-2005 period for the APX and in the 2008-2009 period for Powernext.

The generally converging pattern of the mean and volatility suggests a growing correlation between the four markets. Especially we foresee a high correlation between the APX, Belpex and Powernext after the markets have been coupled in 2006. Therefore we will analyze the development of the correlation level for each market combination. For this a rolling horizon of two years is applied and thereby the utmost left side of the graph describes the correlation over the 1st of January 2003 till the 31st of December 2004. After this point the graph moves on as the two year horizon shifts to the right. Figure 4 shows the correlation development between the EEX and other exchanges, while figure 5 shows the other remaining combinations. Both figures show strong positive correlations and over the entire period there has been a strong upward trend, especially in the first three years. This upward trend continues after a slight decrease

[27] Without these peaks the volatility would be €26.93 instead of €37.47 for the 2003-2005 period.

around 2006 and 2007. We removed the four highest prices[28] as including them results in less clear figures and a worse overview of the overall trend. See the Appendix B for the correlation figures without removal of the four outliers

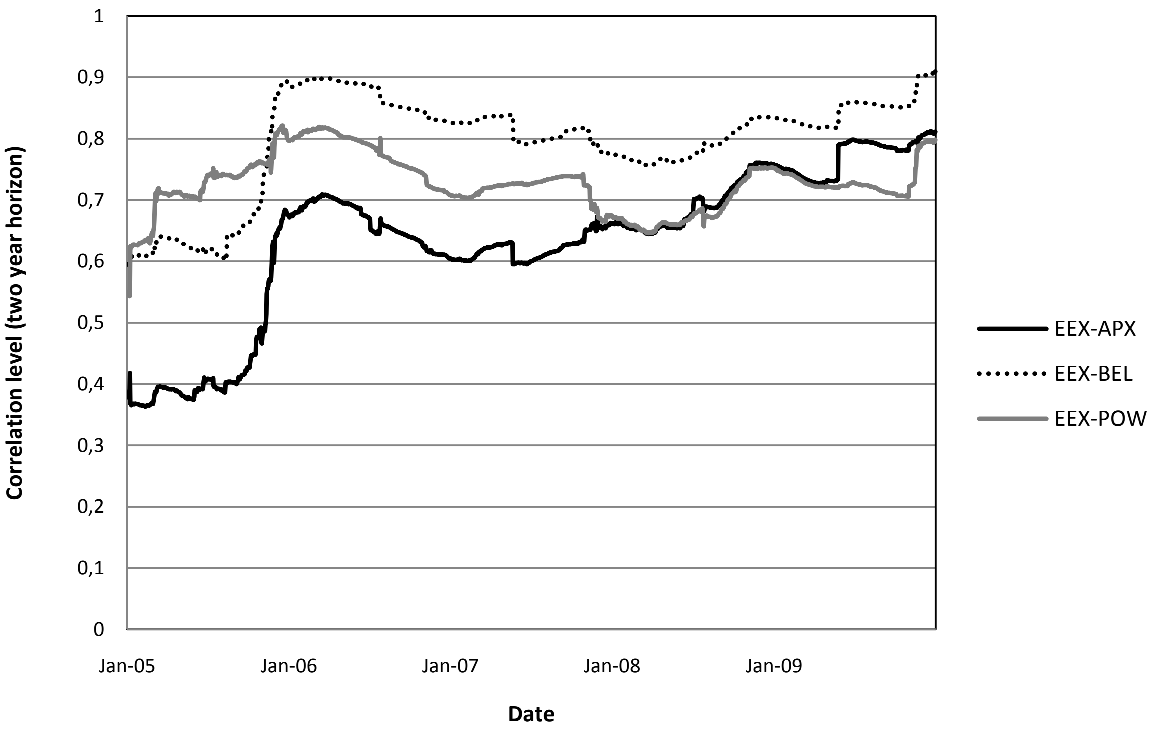

Figure 4. Spot price correlation between the EEX-APX, EEX-BEL and EEX-POW. Two year backwards rolling horizon, base load prices. Period 2003-2009.

In this broad analysis of the spot prices we recognize a trend of a converging volatility, mean and skewness. In addition a downward trend of the volatility can be recognized by comparing the second with the third period. Prior to this decline the years 2006 and 2007 were very volatile for all four markets. Positive skewness remains as well, though it shows a downward lapse. Another development is that correlation levels display an increasing pattern over the research period. All these outcomes seem to indicate the integration of the markets in our study period and support the work of Bunn and Gianfreda (*2010*). They find evidence of market integration as well in their research to spot and futures prices over the 2000-2005 period.

In addition to this analysis we checked for non stationary among the spot prices. Prices for all markets were non-stationary according to the Augmented Dicky Fuller test. A logical explanation for this non-stationary is the seasonality that is common in the electricity markets and described manifold in literature.

[28] We removed the following outliers: APX: €660.34 (10th August 2003), APX: €368.80 (11th August 2003), APX: €637.37 (12th August 2003) ,POW:€612.77 (18th October 2003)

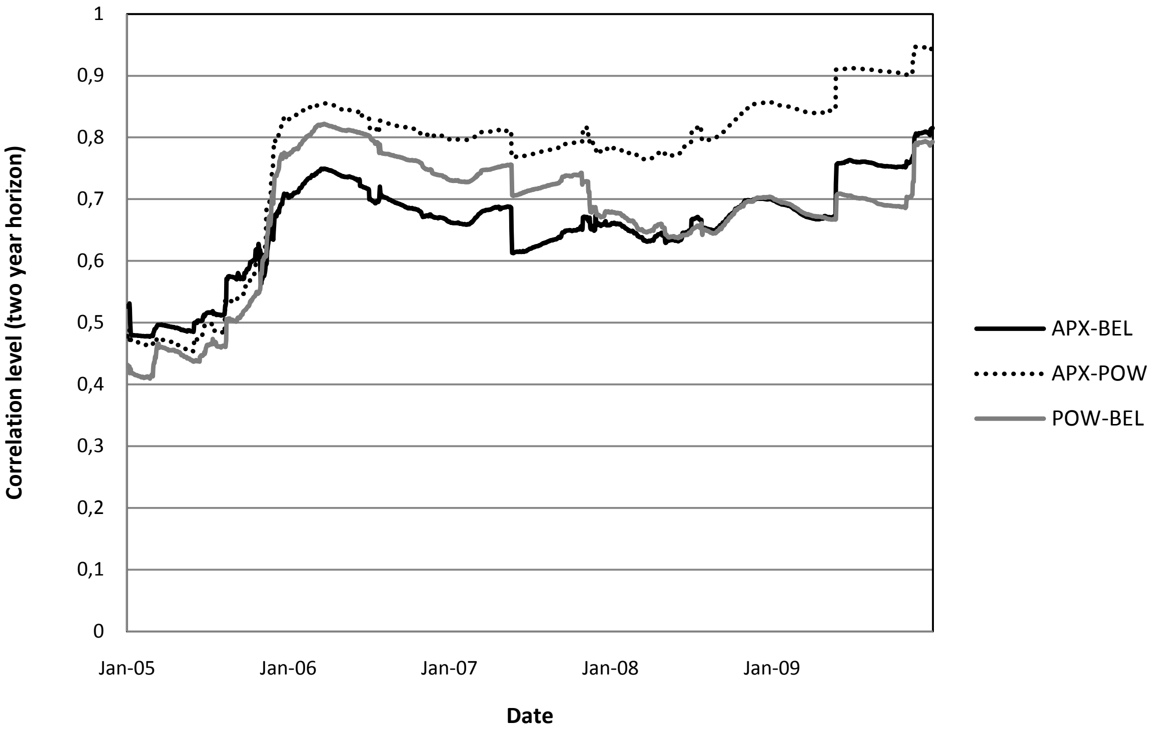

Figure 5. Spot price correlation between the APX-BEL, APX-POW and POW-BEL. Two year backwards rolling horizon, base load prices. Period 2003-2009.

5.2 Futures prices

A comparable price analysis has been performed on one month futures. Figure 6 displays the development of monthly subsequent futures prices in their last month to maturity of all four markets. This month is the one prior to the delivery period. From figure 6 it can be concluded that futures prices show less extreme peaks and a strong correlating pattern, especially in contrast with the scatter plot in figure 3. Moreover in 2008 and 2009 the lines of the four markets show nearly one converged line. The highest futures price of €122 was reached in November 2008 at Powernext.

In table 3 and 4 the mean, standard deviation and skewness of the futures prices are analyzed. From both tables we can conclude that German base load futures have the lowest average price. Although over the three periods the EEX encountered the strongest price increase, comparable to the spot price development. Next to this futures prices converge as well over the three periods, although the remaining price difference among the four markets is larger in comparison with the difference of the spot prices after the convergence.

In comparison to the spot prices the development of the futures' standard deviations shows a contrasting pattern. They increase from around €11 in the first period until €20 in the last period. This volatility level thus rises over the 2003-2009 period, reaching a similar absolute volatility level as the spot prices. Also on a relative basis the futures face a slight volatility increase. Therefore we notice a strong integration of spot and futures markets regarding the behavior of the price volatility. By focusing on the skewness level we detect no strong particular pattern, although the skewness levels appear to be lower in the 2006-2007 and 2008-2009 periods in relation to the first three years.

See figure 7 and 8 for the development of the correlation levels among the four markets. Similar to the correlation analysis for the spot prices, a rolling horizon of two years is applied. The left side of the graphs stands for the correlation over the 1st of January 2003 till the 31st of December 2004. From this point the graph moves on, as the two year horizon shifts to the right. Both figures display a strong increase from the beginning of the study period. From 2006 all correlation levels are above 0.9. As figure 7 makes clear, the EEX shows high correlation levels with all three markets, especially with the APX over the years 2007, 2008 and 2009. Also the Belgian index correlates strong on a constant basis with both coupled markets. Only the APX-Powernext relation is less strong over the years 2005-2008.

Overall futures prices develop in a similar way as spot prices over time; the mean and standard deviations converge. Remarkable is the volatility increase towards the spot price level. This joint convergence in the four spot and futures markets describes the growing dependence between them.

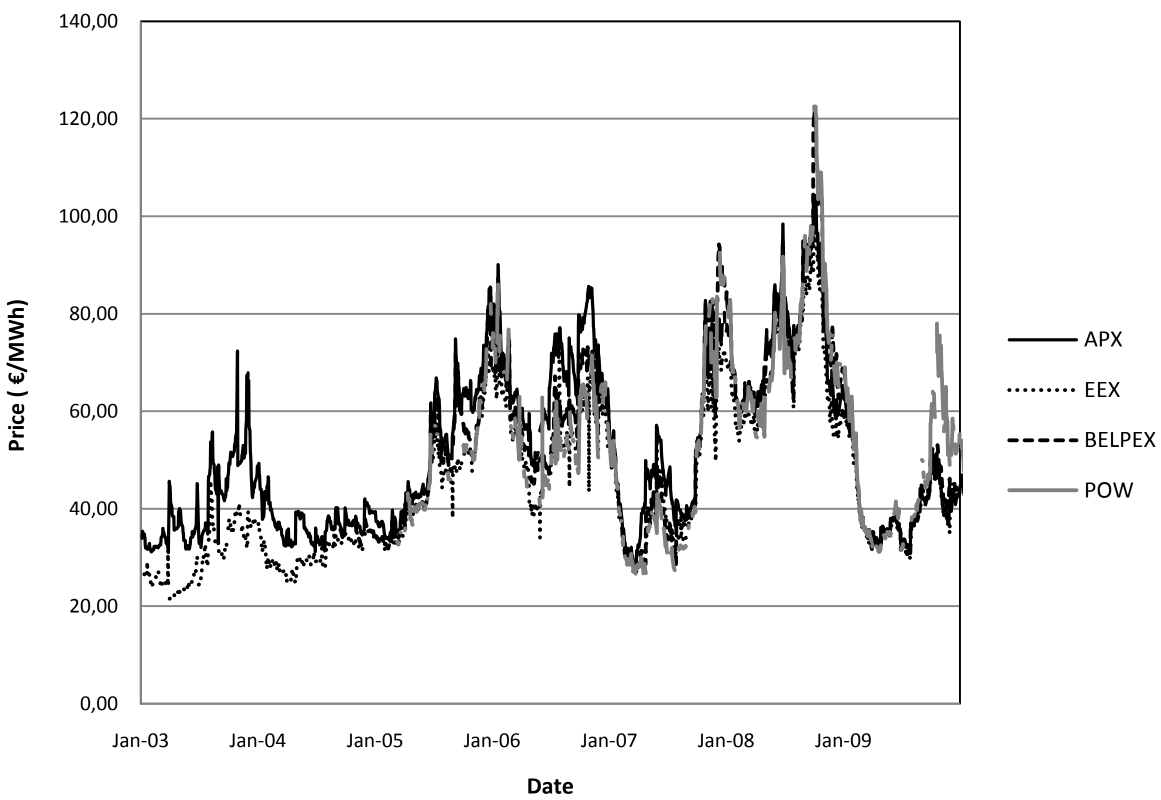

Figure 6. Daily closing futures prices in their last month to maturity for the EEX, the Powernext, the APX and the Belpex. Base load prices. Prices in euro’s per megawatt hour. Period 2003-2009.

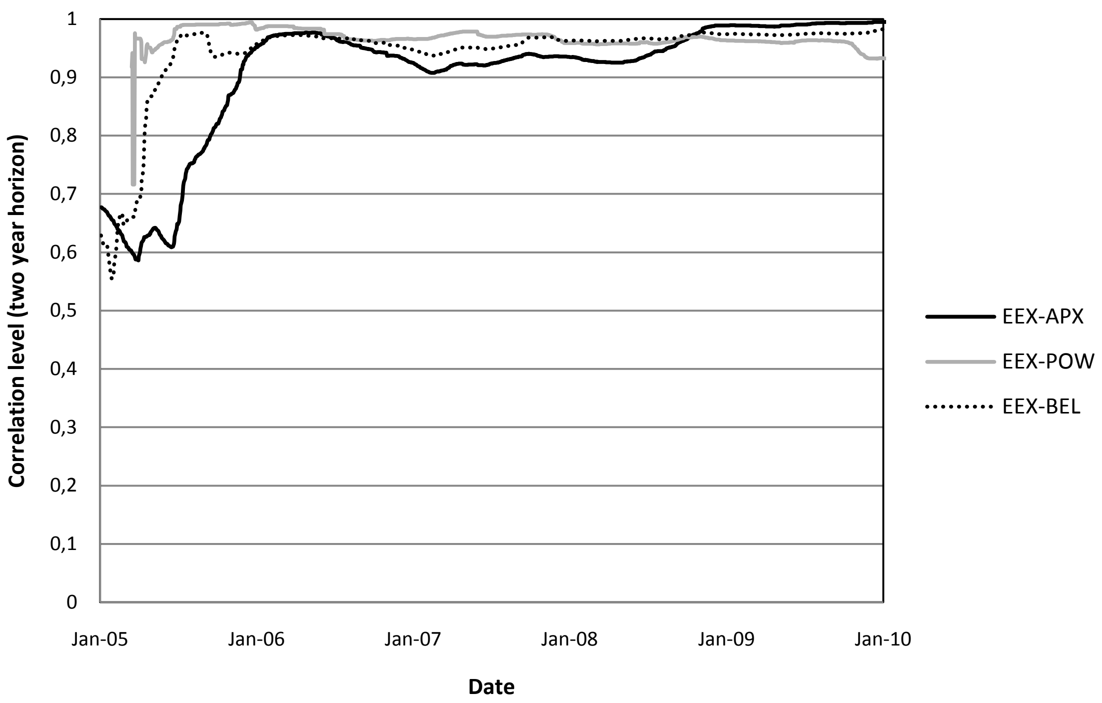

Figure 7. Correlation between base load futures at the EEX-APX, EEX-BEL and EEX-POW. Two year backwards rolling horizon, base load prices. Period 2003-2009.

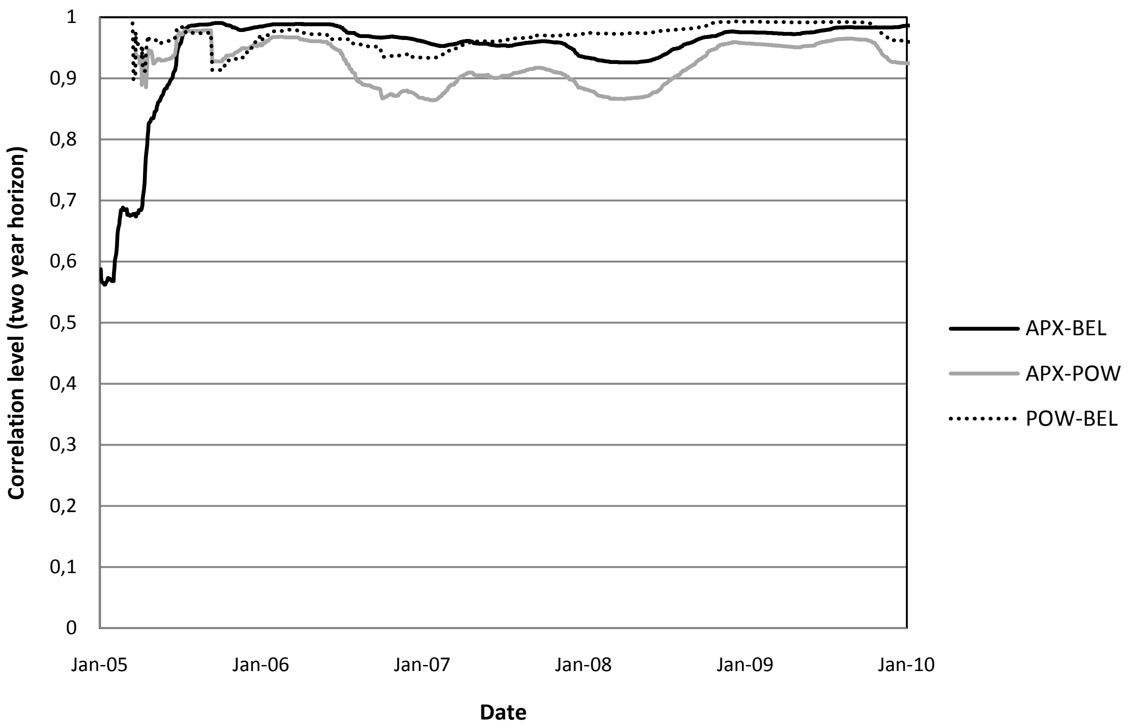

Figure 8. Correlation between base load futures at the APX-BEL, APX-POW and POW-BEL. Two year backwards rolling horizon, base load prices. Period 2003-2009.

Table 3. Descriptive statistics of the daily closing base load futures prices for the study period 2003-2009. Prices are quoted in €/MWh.

	2003-2009				
	EEX	POW	APX	BEL	Average
Mean	45.22	54.93	51.50	53.62	51.32
Median	40.49	53.08	45.65	50.59	47.45
Maximum	98.50	122.50	104.34	123.00	112.09
Minimum	21.50	26.65	28.42	27.30	25.97
Std. Dev.	15.71	18.40	16.79	18.18	17.27
Std. Dev.(%)	34.73%	33.49%	32.60%	33.90%	33.65%
Skewness	0.83	0.76	0.73	0.79	0.78
Kurtosis	3.09	3.55	2.54	3.29	3.12

Table 4. Descriptive statistics of the daily closing base load futures prices over different periods; 2003-2005, 2006-2007, 2008-2009. Prices are quoted in €/MWh.

	2003-2005					**2006-2007**					**2008-2009**				
	EEX	POW	APX	BEL	Average	EEX	POW	APX	BEL	Average	EEX	POW	APX	BEL	Average
Mean	35.60	48.09	43.35	45.44	43.12	49.73	50.15	58.21	53.71	52.95	54.88	61.47	57.92	59.36	58.41
Median	33.19	46.00	39.14	40.38	39.68	50.31	50.50	59.16	53.30	53.32	55.28	61.50	59.87	60.43	59.27
Maximum	72.95	82.00	85.48	84.15	81.14	80.90	92.50	90.08	94.21	89.42	98.50	122.50	104.34	123.00	112.09
Minimum	21.50	32.60	31.02	32.13	29.31	26.50	26.65	28.42	27.30	27.22	29.63	31.00	31.43	30.52	30.65
Std. Dev.	10.08	11.12	11.27	12.24	11.18	12.73	16.09	15.31	15.95	15.02	17.62	20.22	19.78	21.39	19.75
Std. Dev.(%)	28.31%	23.12%	26.00%	26.95%	25.92%	25.61%	32.09%	26.29%	29.70%	28.37%	32.11%	32.89%	34.15%	36.03%	33.82%
Skewness	1.27	1.04	1.29	0.92	1.13	0.02	0.39	-0.15	0.18	0.11	0.50	0.53	0.38	0.56	0.49
Kurtosis	4.42	3.81	3.96	3.02	3.80	1.95	2.40	1.91	2.22	2.12	2.20	3.10	1.99	2.64	2.48

CHAPTER 6 Expectations regarding the risk premium development

The price analysis of the spot and futures might give an indication with regard to the development of the risk premium. We expect to find on average positive premiums as well, as empirical studies prove the existence of non-zero risk premiums on a one-day horizon (for example Bessembinder and Lemmon, *2002*) and on futures with a longer maturity (for example Botterud et al., *2009*). On top of that we will try to assess an expectation regarding the risk premium development, based on results of prior research and our analysis of spot and futures prices. This analysis showed us the convergence of the price level, volatility and skewness at the four markets over the 2003-2009 period. In addition the volatility in the spot markets has declined after the turbulent years of 2006-2007.

First of all we focus on the leading literature of Bessembinder and Lemon (2002) to assess a potential expectation. They found proof – however not significant - for a negative relation between unanticipated variance and the expected forward risk premium, while the skewness level is positively related. It should not be forgotten that their equilibrium model, on which they have based their findings, holds specific assumptions, which are discussed in the literature section of this thesis. Another point of attention is the approach and argumentation around this model, which is based on the desire of market participants to hedge their risk; high variance leads to going short in futures for generators to secure their profit. In line with their research Furio and Meneu (*2010*), Longstaff and Wang (*2004*) and Pietz (*2010*) found support for the negative relation between variance and the risk premium and the positive relation with skewness on the other hand.

A strong trend that results from our spot and futures analysis is the declining volatility and variance[29]. In line with the relation described above, we can expect higher premiums over time. However according to Botterud et al. (*2009*) and Redl et. al (*2009*) the implications of this theoretical model are not feasible to assess the risk premium in the current competitive market. For instance due to the assumption that there are no outside speculators involved. Next to this Botterud found no proof for this model in the Nord Pool market. Also Marckhoff and Wimschulte (*2009*) and Lucia and Torro (2008) investigated the Nord Pool market and found some proof for the B-L model.

Finally we will not base our expectation on the B-L model, due to these mixed outcomes in the literature and the specific assumptions the model holds. Moreover the volatility has decreased over the last years, similar to the skewness. As a result both findings should oppose each other in their effect on the risk premium according to the B-L model. Thus, without using the specific B-L model we construct our expectation on the desire for hedging from the side of demand and supply. As Bessembinder (*1992*) and Pietz (*2009*) described, volatility drives the demand for hedging. It mainly effects the demand side on the short term, which accounts for one month futures. A high volatility, which can result in high peaks at electricity markets, creates uncertainty and stimulates the short term demand for futures. In contrast to this generators have to desire to hedge their production as well, however over a longer period of time.

[29] Variance is calculated as the square of the standard deviation (volatility).

This is done to secure their investments with steady cash flows. A high supply of futures over the long term results in a negative premium on futures with a longer term to maturity.

For our expectation we have seen that the price risk on the electricity markets decreased over the 2007-2009 period. There were less extreme peaks and the volatility decreased. Therefore we foresee a lower demand for futures after the tumultuous years of 2006-2007, with a declining price and premium as a result. Thus our expectation is that risk premiums will decline after 2007.

CHAPTER 7 Results

7.1 Development of the risk premium

The development of the observed risk premium has been analyzed for the German (EEX), France (Powernext), Dutch (APX) and Belgian (Belpex) electricity market. Figures 9.A till 9.D show the outcomes of this analysis with the development of the average spot and one month ahead futures prices in €/MWh for each market. However most important is the development of the risk premium, which is expressed in percentages and moves around the x-axis.

Figure 9.A represents the EEX and shows that the monthly risk premium behaves volatile, with both negative and positive risk premiums. A visual analysis points out that observed premiums fluctuate the most intense in the years 2006-2007. In these years the observed premium went up to almost 50% and down to minus 60%. Also the first three years show a number of strong negative risk premiums. However in the last two years the premium behaves less extreme with values closer to zero. Over the entire period especially the negative peaks seem to decline, though from 2006 the positive peaks are in decline as well.

The risk premium in France (figure 9.B) shows a varying pattern too as negative and positive peaks appear over the 2003-2009 period. The last negative spike is clearly formed around the high price in October 2009. Without this last distortion in October the graph shows a declining pattern as well over the final years. Similar to the EEX, there were almost no negative premiums and the positive premiums declined as well. Nevertheless the strong peaks at the end of 2009 make it difficult to signal a specific trend around the risk premium development, although the period 2008-2009 is less volatile.

We continue with the APX in figure 9.C. The first year of 2003 shows strong negative risk premiums up to -140%, which are followed by declining positive premiums till 2005. Then a volatile pattern arises over 2005, 2006 and 2007 with both positive as negative premiums. This period is followed by the last two years, which shows lower positive and almost no negative premiums. Similar to the development at the EEX and Powernext the premiums are located closer to zero in the final years. Also here the trend of the premium appears to be downwards in the direction of zero, in a less volatile pattern.

At last we will analyze the risk premium at the Belgian Belpex (figure 9.D). This exchange shows a similar pattern again with volatile premiums over the years 2005, 2006 and 2007. Even negative premiums of more than minus 50% appear. The final two years are less volatile with less extreme negative premiums. The trend in Belgium is one of more steady premiums that are generally positive over the last two years. If negative premiums are observed, they are very close to zero.

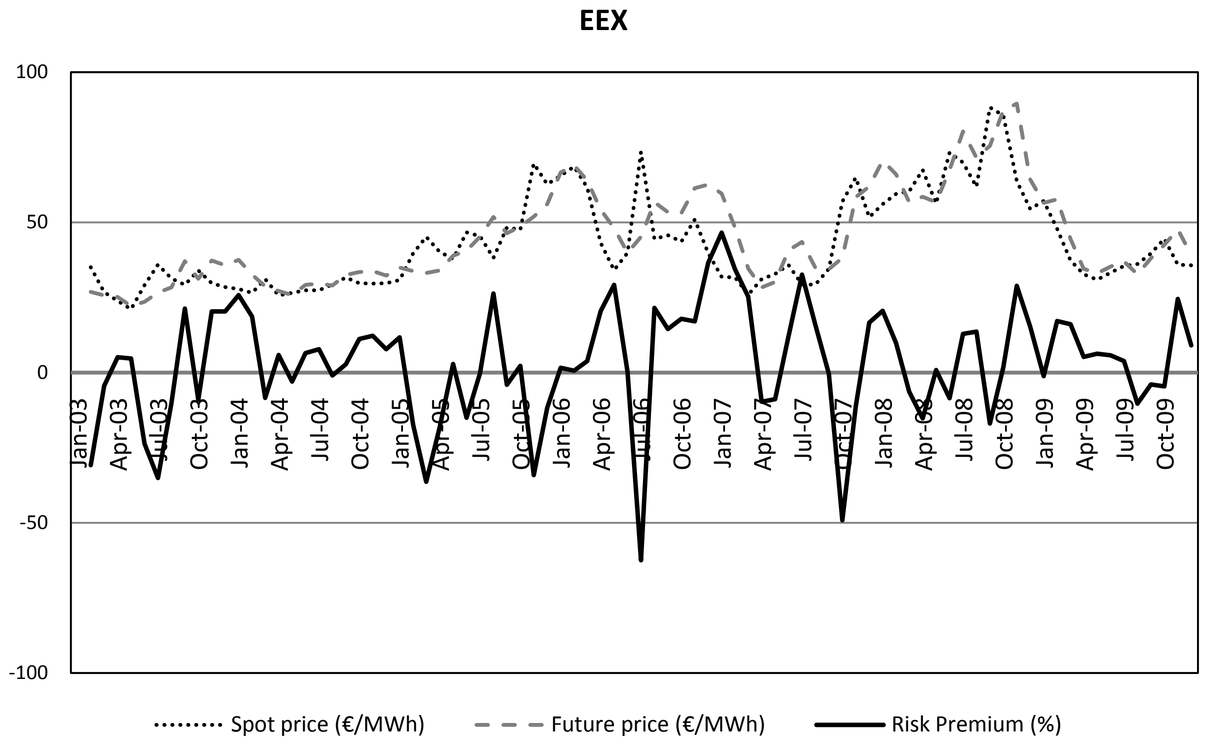

Figure 9.A. Development of the relative risk premium (%) on monthly futures at the EEX. Average base load spot and futures prices are included. Period 2003-2009.

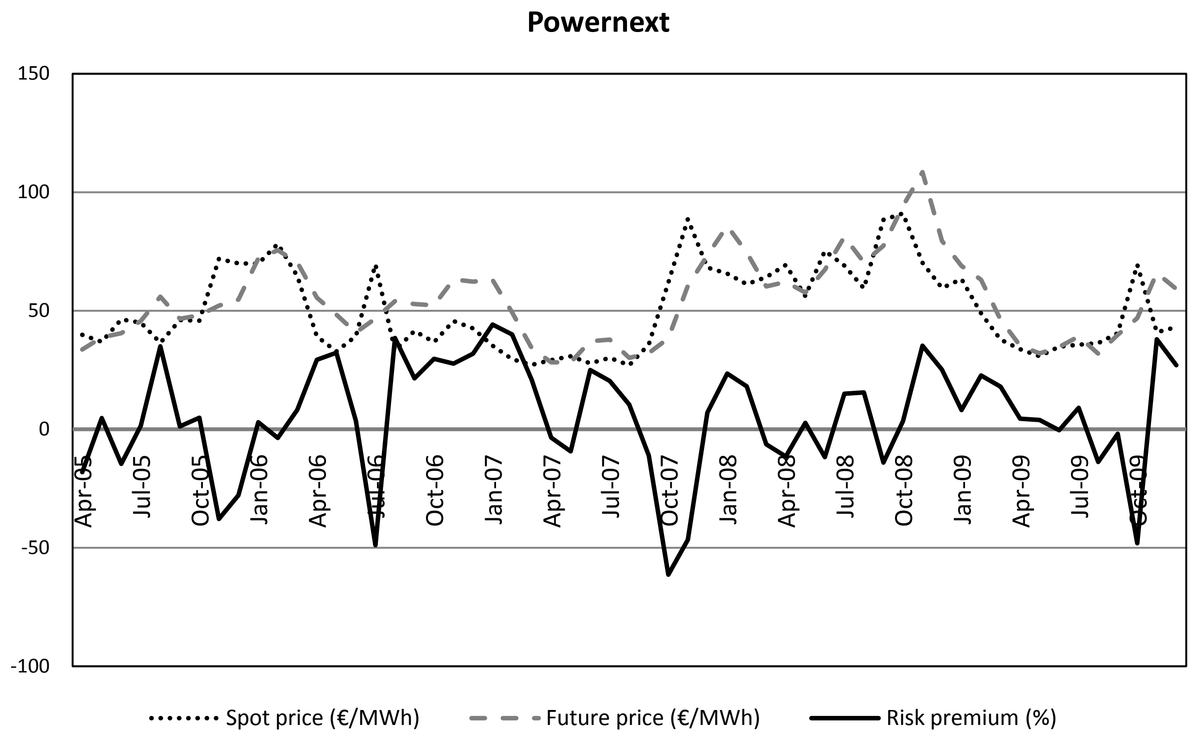

Figure 9.B. Development of the relative risk premium (%) on monthly futures at the Powernext. Average base load spot and futures prices are included. Period 2005-2009.

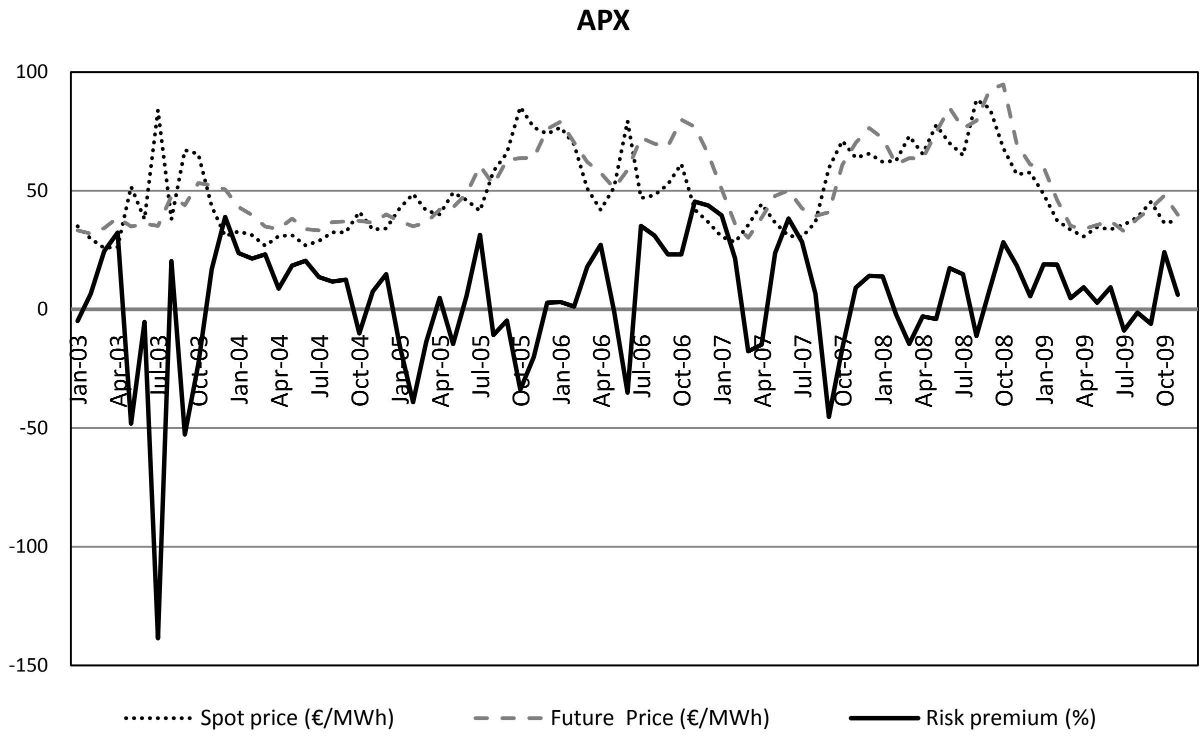

Figure 9.C. Development of the relative risk premium (%) on monthly futures at the APX. Average base load spot and futures prices are included. Period 2003-2009

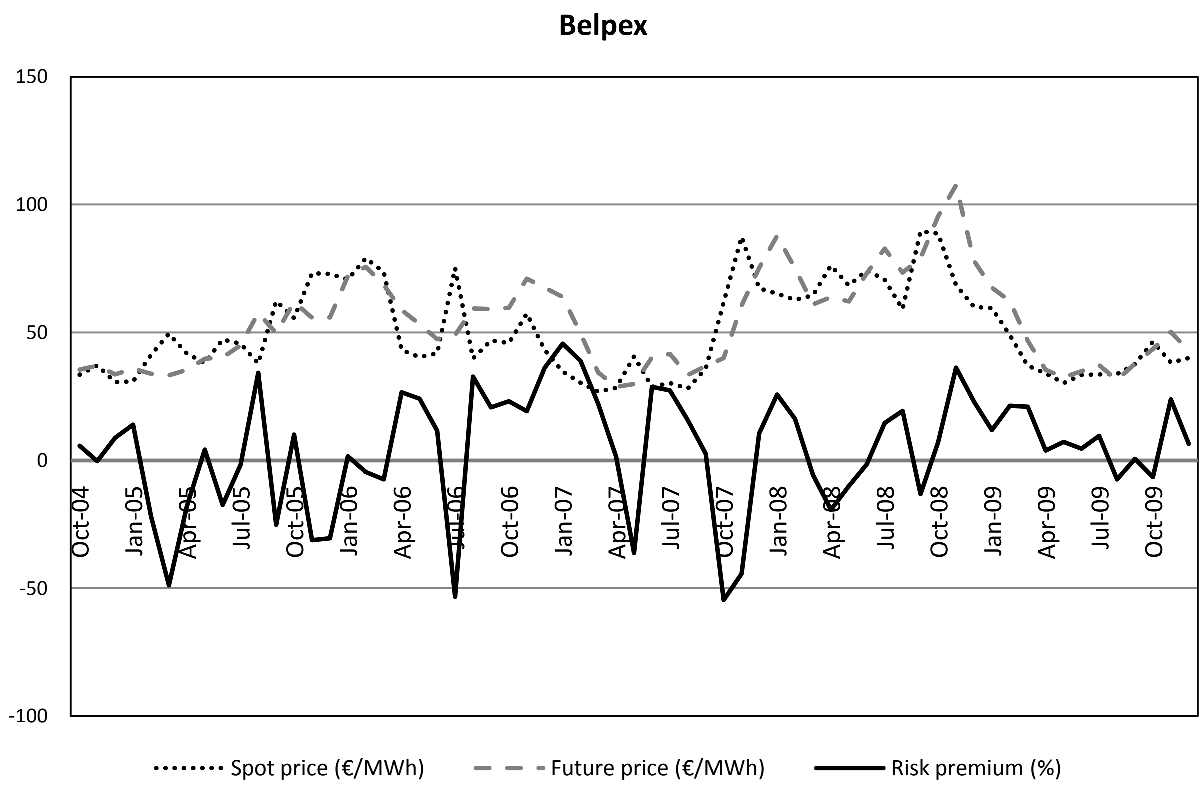

Figure 9.D. Development of the relative risk premium (%) on monthly futures at the Belpex. Average base load spot and futures prices are included. Period 2004-2009.

Over the entire study period of seven years all observed risk premiums show no consistent value. Negative premiums are followed by positive premiums, sometimes in an extreme volatile pattern. In addition the well known seasonality of electricity prices can be recognized as summer and winter premiums are on average higher in comparison with those in the spring and autumn[30]. Nevertheless over the 2003-2009 period some clear overall patterns can be recognized at the Western European markets.

First of all we can notice that especially the years 2006 and 2007 were the most volatile years for the premiums. They diverged from -50% up to 50% and almost no observed premiums ended close to zero. This implies that the expected spot price consistently differed from the realized spot price at all exchanges. A second pattern is the decline of the risk premiums over the final years. There appear almost no negative premiums and the positive premiums seem to move in the direction of zero as well. In order to analyze the development of the risk premium in more detail, we will apply regression (A) and divide the study period into three sub periods: 2003-2005, 2006-2007 and 2008-2009.

$$\text{(A)} \qquad \pi\,(T) = \mu + \varepsilon_t$$

The results are displayed in table 5 and for each market and sub-period the average risk premium has been calculated (μ). One can see that in France the average risk premium is significantly positive at the 10% level over the entire period. However the other three markets show non significant positive risk premiums, while the average risk premium of the four markets is 4.40%. By dividing the entire period into sub periods table 5 also gives a good overview of the development of the premium. It shows that the average of the risk premiums is negative over the first period 2003-2005, which implies that generally spot power was cheaper on the futures market than on the spot market. Notice that the average risk premium was -4.30%, though the situation in each market varied. Germany had a small negative premium of -1.43% in contrast with -7.83% in Belgium.

The second sub period results in positive risk premiums for all markets, while the APX has the highest premium with 12.11% that is significant at the 5% level. Compared with the other three markets – which show no significant premium - this risk premium is notably higher. Next to this the premiums of the EEX, Powernext and Belpex are all situated around 8% and therefore more converged. Then in the third sub period all average premiums are lower and significant from zero. For the EEX, the Powernext and the APX the premiums declined in comparison to the second period, while only the Belgian risk premium remained identical in the third sub period, though now significant. Therefore the development of the observed risk premiums suggest an overall downward trend over the last years. In addition we can recognize a convergence among the relative risk premiums as well, identical to the development of spot and futures prices. On top of that table 5 demonstrates that risk premiums have become less capricious, as the volatility is remarkable lower in the final period

[30] Results not included in this thesis as we focus on the overall development of the risk premiums.

Table 5.

Regression of the monthly risk premiums, $\pi\,(T) = \mu + \varepsilon_t$, μ is the mean of the risk premiums. H_0: μ=0 against H_1: $\mu \neq 0$.
* significant at 10% level; ** significant at 5% level; *** significant at 1% level. Results are corrected for heteroskedasticy consistent coefficient covariance (Newey-West). Standard Deviation (*SD*) in percentages included in the table.

	2003-2009		2003-2005		2006-2007		2008-2009	
Index	μ	*SD (%)*	μ	*SD (%)*	μ	*SD (%)*	μ	*SD (%)*
EEX	0.0335	0.189	-0.0143	0.173	0.0850	0.251	0.0515**	0.122
Powernext	0.0557*	0.240	-0.0572	0.216	0.0868	0.283	0.0669*	0.191
APX	0.0454	0.263	-0.0222	0.329	0.1211**	0.246	0.0682***	0.115
Belpex	0.0413	0.230	-0.0783	0.219	0.0786	0.286	0.0787**	0.140
Average	**0.0440**	**0.231**	**-0.0430**	**0.234**	**0.0929**	**0.2665**	**0.0663**	**0.142**

Table 6.

Linear trend line regression of the monthly risk premiums against time. $\pi\,(T)_t = \alpha + \beta T_t + \varepsilon_t$. T represents subsequent months in a increasing linear way. T=1 for January 2003. T=2 for February 2003, and so on. T-Statistics between brackets. * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Results are corrected for heteroskedasticy consistent coefficient covariance (Newey-West). Regression performed on different (sub) periods.

	2003-2009		2003-2006		2007-2009	
Index	α	β	α	β	α	β
EEX	-0.0151 (-0.3323)	0.0012 (1.4218)	-0.0446 (-0.7028)	0.0023 (0.9678)	0.1067 (1.2670)	-0.0024 (-0.7035)
Powernext	0.0422 (0.5897)	0.0005 (0.2527)	-0.1274 (-1.4330)	0.0168** (2.6255)	0.0762 (0.6653)	-0.0012 (-0.2506)
APX	-0.0249 (-0.2735)	0.0017 (1.0653)	-0.0902 (-0.6675)	0.0046 (1.1069)	0.1194 (1.4157)	-0.0022 (-0.6872)
Belpex	-0.0290 (-0.4736)	0.0022 (1.6235)	-0.1430 (-1.4634)	0.0106* (1.8046)	0.0805 (0.7677)	-0.0006 (-0.1615)

7.2 Trend regression

The average risk premium at each market increases from the first to the second period and declines over the two subsequent final years. In line with this finding we will use regression (B) for a more specific analysis and to test the trends in the development of the premiums. For that reason the slope of the trend line (β) of regression (B) is estimated for the entire research period, though also over the years 2003-2006 and 2007-2009. The entire research period is split in the middle of the sample in order to remain enough data points for a regression. Next to this we are interested in the development of the premium over the final years, as spot and futures appear to be less volatile.

$$\text{(B)} \qquad \pi\,(T)_{\boldsymbol{t}} = \alpha + \beta T_t + \varepsilon_t$$

Table 6 shows the results of the different regressions. Despite the lack of significance, the different regressions for each market lead to identical patterns in the trend lines. Over the period 2003-2009 the slope of the trend line is positive for each market. It demonstrates an overall rise of the risk premium from 2003 to 2009; from on average negative risk premiums towards on average positive risk premiums. Per month risk premiums have risen roughly 0.1%. However these positive trend lines are not caused by constant rising positive premiums. For the EEX, the APX and the Belpex the years 2006-2007 are the most tumultuous, but after the highest positive observed premiums around January 2007 all three markets show declining positive risk premiums. As a consequence the marginal positive trend over 2003-2009 seems to be caused by less extreme negative risk premiums at the EEX, APX and Belpex in the years 2008-2009.

The second column in table 6 displays the regression of the premiums against time over the 2003-2006 period. All regressions result in positive β's, while only the French coefficient is significant at a 5% level. On top of that the Powernext shows the most positive trend line. However it is based on only 21 premiums, as future data was available from September 2004. Overall all markets thus had to deal with on average rising risk premiums until 2007. Then the 2007-2009 periods follows with negative the trend lines at all markets, as table 5 already suggests. None of these trend lines is reported as significant at the 10% level or below, while the EEX has the most negative slope. Despite the non significance this regression over the final years, together with table 5, supports a conclusion that risk premiums decline over the last three years at the EEX, the APX and the Belpex.

7.3 The risk premium in relation to zero

The overall focus in this thesis is on the development of the average level of the risk premium. Another point of view is to analyze the risk premium in its relation to zero. As discussed before, the risk premium theory has its foundation in the expected spot price. For that reason futures more accurately resemble realized future electricity prices, when it appears that observed risk premiums end closer to zero. Figures of the risk premium developments at the EEX, the APX and the Belpex already demonstrated that premiums stay closer to zero over the last years. Therefore we are interested in a more detailed analysis of this visual insight and perform an additional regression. For this we will make all risk premiums positive and regress them against time, similar as in regression (B), to test their development in relation to zero over time.

The results are displayed in table 7, with a similar division of sub periods as in table 6. As we can see in table 7 the risk premiums declines in relation to zero over the entire study period, versus an increase for the level of the risk premium in table 6. However only at the APX the slope of the trend line is significant. The next column, 2003-2006, confirms the volatile behavior of the risk premium around 2006-2007. While the risk premium for the APX declines, the other markets show a positive trend line, which implies that till 2007 the risk premiums rose in relation to zero for. The coefficients of the Belpex and the Powernext are significant, though respectively based on only 27 and 21 observations[31].

In contrast with significance level of the results in table 5, table 6 shows strong significant declining risk premiums over the years 2007-2009. The fastest average decline can be found at the APX and the Belpex with a coefficient value of -0.6%. This implies that over the last three years the risk premiums at the APX and Belpex converged to zero with a yearly average of 7.5% percent.

Table 7.

Linear trend line regression of the monthly risk premiums against time. All risk premiums transposed in positive values to asses risk premium development in relation to zero. $\pi\,(T)_t = \alpha + \beta T_t + \varepsilon_t$. T represents subsequent months in a increasing linear way. T=1, January 2003. T=2, February 2003, and so on. T-Statistics between brackets. * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Results are corrected for heteroskedasticy consistent coefficient covariance (Newey-West). Regression performed on different (sub) periods.

	2003-2009		2003-2006		2007-2009	
Index	*α*	*β*	*α*	*β*	*α*	*β*
EEX	0.1584 (6.1706)	-0.0003 (-0.5435)	0.1195 (3.3545)	0.0012 (0.8673)	0.2372*** (5.2431)	-0.0050** (-2.6311)
Powernext	0.2033*** (4.6065)	-0.0004 (-0.2535)	0.0805** (2.5366)	0.0110*** (4.9144)	0.2297*** (3.7243)	-0.0023 (-0.6964)
APX	0.2802*** (4.6990)	-0.0021 (-2.0023)**	0.2807*** (2.9859)	-0.0025 (-0.8146)	0.2720*** (6.970259)	-0.0061*** (-3.8883)
Belpex	0.2238*** (5.1810)	-0.0012 (-1.0774)	0.1110* (2.0381)	0.0062* (2.0192)	0.2991*** (8.1648)	-0.0065*** (-4.3559)

[31] The first available risk premium is for the Belpex is in October 2004 and for the Powernext in March 2005.

CHAPTER 8 Conclusion

This thesis examined the development of the observed risk premium on monthly electricity futures in the Western European markets; Germany, France, the Netherlands and Belgium. For this research the period from January 2003 till December 2009 is used. As we start with a data analysis of the spot and futures prices over this period, we demonstrate the convergence of the four markets regarding price and volatility. In addition we can identify a general volatility of 50% at the four markets until 2007. However from 2008 the volatility changed to 40% for the remaining final years. Therefore we can conclude that the volatility of the spot price and the price risk has declined.

Next to this the correlation has grown to a high level - above 0.9 - in both the spot and futures markets, which is a substantial increase in comparison with the results of Pereira da Silva and Soares (*2008*). They found a maximum correlation of 0.67 between Powernext and the EEX in the period 2002-2004. From our analysis, which shows this high correlation together with the convergence of the mean and volatility at the spot and futures markets, we can conclude that markets behave more and more as one single market. On top of that the volatility, and consequently the price risk, declines as well.

An important contributor to these changes might be the market coupling in Belgium, that has been active since the end of 2006. By matching demand and supply in France, the Dutch and Belgium prices were equal in all three markets for more than 50% of the time. Only France demonstrated one extreme power spot price in October 2009. However we perform no investigation to the explicit contribution of the Belgian market coupling.

After the analysis of the spot and futures prices, which form the fundamentals of the observed risk premium, we continue with its development. In our expectation we describe that dye to lower volatility the demand for hedging on the short term should reduce. Therefore we expect a decline in the price – in relation to the realized spot prices - of the monthly futures that mature within in one month. This decline of the futures prices should lead to lower observed risk premiums. In general we can conclude that we find proof for this expectation and that risk premiums show a declining trend.

The period 2006-2007 can be regarded as a period with on average high risk premiums at all markets, though not significant from zero. The high volatility of the spot prices in the years 2006 and 2007 seems to be expressed in volatile and high risk premiums as well. However the average of the premiums in the 2008-2009 period is lower and differs significantly from zero. As expected the trend line regression over the period 2007-2009 results in negative coefficients at all four markets, although not significant. Therefore we can conclude that after the volatile years of 2006-2007 the development of the observed risk premium shows a slow and gradual decline. One has to bear in mind that this is an overall general conclusion since this decline is the strongest at the APX and the EEX, while the Powernext shows high premiums around October 2009.

Further it is remarkable that Germany showed the least varying risk premiums in the first years, followed by the turbulent period of 2006-2007. It appears that the Western European markets influenced each other, which did not turn out positive for Germany in the first place, although it demonstrates the integration of the markets.

In addition to the analysis of the average level of the risk premium, we investigate the premium in its relation to zero. A similar trend analysis shows strong significant results of converging risk premiums towards zero in all four markets in the period 2007-2009. This adds to our conclusion that futures have become better forecasters of future spot prices in the final years.

The research in this thesis is based on a limited number of risk premiums as there is roughly seven years of available data. As a result the sub periods reduced the sample even further. We are aware of the relatively low sample size that has been used to perform the trend regressions, as we base our main conclusion on 36 determined risk premiums for each market. However the similar outcomes among all markets demonstrates a general trend and we almost find no opposing signs in the entire thesis, which strengthens our conclusion.

As we find declining risk premiums parallel to declining volatility at the spot markets, it is of interest to further research this possible relation. In our expectation we linked a declining volatility declining risk premiums in the light of the hedging theory. However the B-L model suggests a reverse relation. Therefore we suggest a regression on the risk premium, volatility and skewness to test the outcomes of the B-L model over our research period. Another aspect that has not been mentioned so far is the credit crunch and the global recession that followed. From the end of 2008 all four markets show overall lower prices as demand dropped. Can the recent developments of the declining risk premiums be linked to this price decline? In addition it will be of great interest to analyze the further development of the premium and investigate if its gradual decline continues as more data will come available. This will improve our knowledge about the relation between current and future spot prices of a commodity that cannot be stored.

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APPENDIX A – Other resources

Appendix Trilateral Market Coupling (2006), *http://www.belpex.be/uploads/media/Algorithm_Appendix_v4.6_PPO-adaptations_final.pdf*

Belgian Commission for regulation of gas and Electricity. Study (F)100218-CDC-947, (2010)

De Nederlandse Energiemarkten in 2009. Dutch Energychamber, NMA (2009)

Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity

Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC

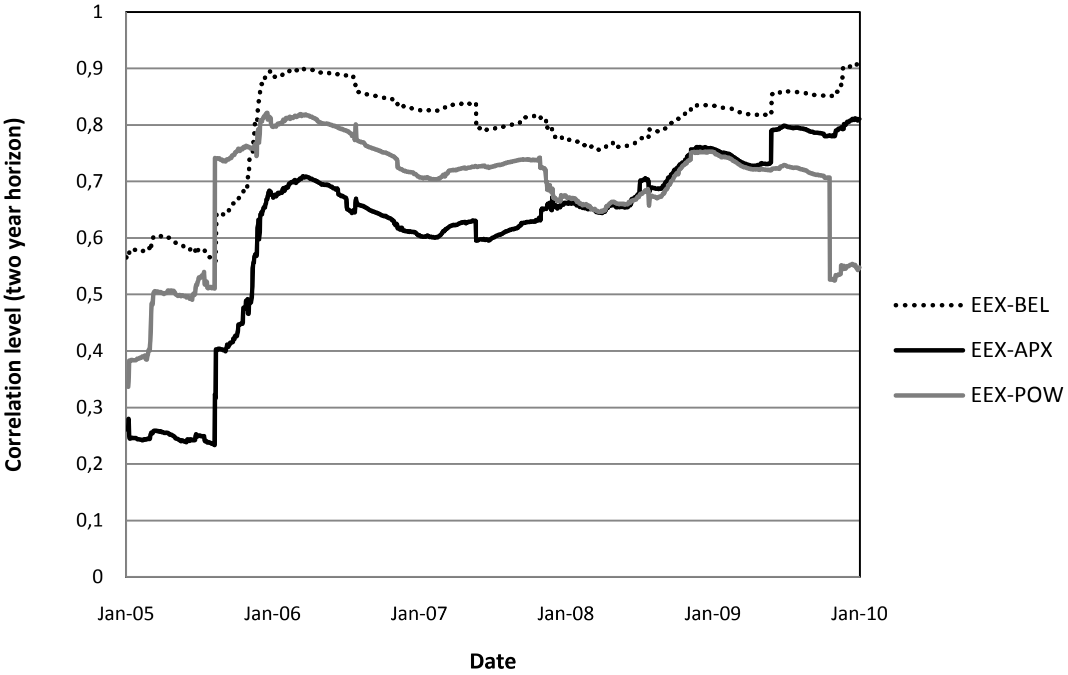
Website APX: *http://www.apx.nl*

Website Belpex: *http://www.belpex.be*

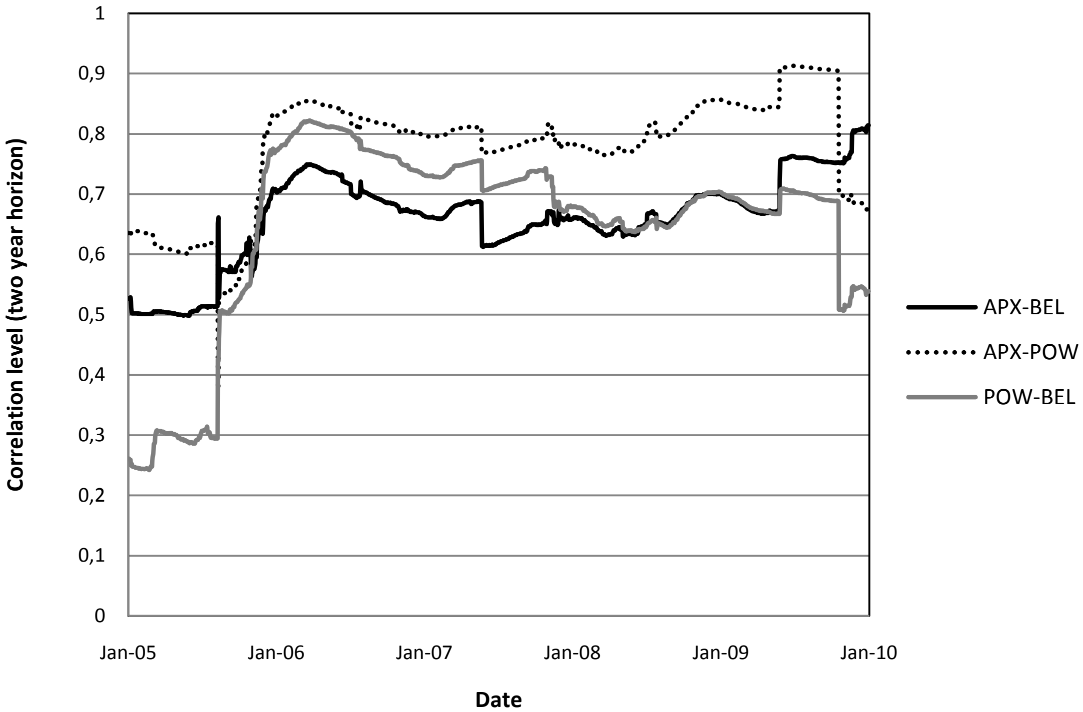
Website EEX: *http://www.eex.com*

Website Powernext: *http://www.powernext.com*

APPENDIX B – Correlation graphs (all prices included)



Appendix B.1. Base load spot price correlation between the EEX-APX, EEX-BEL and EEX-POW. Two year rolling horizon. Without removing high prices.



Appendix B.2 Base load spot price correlation between the APX-BEL, APX-POW and POW-BEL. Two year rolling horizon. Without removing high prices.