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The effect of TLC electricity market coupling on the forecast power and evidence of time-varying risk premiums of the forward basis

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PREFACE AND ACKNOWLEDGEMENTS

During my master study in Financial Economics at the Erasmus University Rotterdam, I followed the seminar Energy Finance. The market for energy is a challenging one with unique characteristics, which makes it a very interesting field for academic research. Before you lies my master thesis, with which I hope to contribute to this matter.

Before getting theoretical, I would like to thank a few people. Thank you dr. Ronald Huisman, for sparking my first interest in the field of Energy Finance and for your enthusiastic way of teaching. Thank you to his PhD-candidate and my supervisor, Mehtap Kilic: you have been of tremendous support during the process of this research, with your valuable insights and suggestions. Last but not least, thank you to my parents and my late grandmother: I would not be where I am today without your on-going support throughout the years.

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ABSTRACT

In the last decade, different efforts have been taken to increase efficiency on the European electricity market; one of them is the Trilateral Market Coupling (TLC) launched on November 21, 2006. This market mechanism linked the Dutch, Belgian and French power exchanges (APX, Belpex and Powernext, respectively) and their Transmission System Operators, or TSOs (TenneT, Elia and RTE, respectively). Since electricity is a non-storable commodity, the theory of storage cannot be applied for analysing forward prices. The so-called expectations theory of Fama and French [1987] states that electricity forward prices contain information about the expectation of market participants of the (average) spot price in the delivery period, and also a risk premium which compensates producers for the uncertainty involved in committing to sell against fixed prices. This research seeks to shed more light on this matter and at the same time studies the effect of TLC market coupling on the evidence of forecast power and time-varying expected risk premiums of the one-month, one-year and quarterly forward basis. Next to this, skewness and variance are analysed in relation to the forward risk premium to test the statements made by Bessembinder and Lemon [2002]. Finally, the seasonal effect on forward risk premiums is part of study to test some findings of Cartea and Villaplana [2008].

We provide significant evidence in support of the expectations theory. Where forecast power of one-month and quarterly forward prices was strong before TLC market coupling, it also contains evidence of time-varying risk premiums afterwards. Forecast power of one-year forward prices has grown even stronger than before coupling. Our results do not uniformly support the findings of Bessembinder and Lemon [2002]; the same holds for the seasonal effect on forward risk premiums [Cartea and Villaplana, 2008].

Keywords: Forward markets, TLC market coupling, expectations theory, risk premium, electricity prices

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1 Introduction

The market for electricity in Europe has not always been as liberal as it is nowadays. Only since the 1990s the internal market for electricity has gone through a liberalisation process, which became official by adopting the first electricity directive in 1996 [EC, 1997]. According to Redl et al. [2009], the goal of this directive and other liberalisation efforts of the electricity supply industry, was to introduce competition as precondition for an efficient energy supply. Next to this, prices moved from being based on the cost of producing electricity towards a more market orientated formation. Last but not least, short- and long-term trading in electricity on power exchanges became possible; these are the markets for spot and forward (or futures[1]) electricity prices, respectively.

This fresh, competitive environment brought along new risks for all electricity market participants. One of the most important characteristics of electricity is its non-storability (see Fama and French [1987] and Lucia and Schwartz [2002], among others), causing the inability of supply to react in a flexible way to sudden changes in demand. Supply is limited and can be substantially influenced by environmental or technical shocks, such as long periods of drought or unexpected outages of generation units. Demand can fluctuate heavily because of unexpected weather conditions or other unforeseen circumstances. As a result, the market for electricity is characterised by having time-varying (high) volatility with the possibility of (significant) price spikes. Other characteristics are mean-reversion and seasonality. Redl et al. [2009] state that all these characteristics can be attributed to the convex supply curve, price-inelastic demand in the short run and, again, the non-storability of electricity.

To allow for management of the price risk involved in trading on the electricity market, long-term contracts such as forwards were introduced. By purchasing a forward from a producer of electricity, a power retailer can hedge the risk of agreeing to deliver to clients against a fixed price in for example 2012. In the forward contract, the electricity price against the company will purchase power in the market in 2012 is fixated; hence the risk manager reduces price risk. Timing when to buy forward contracts is the most difficult part, because one does not know the spot price of the day after [Huisman and Kilic, 2010].

The more efficient the market, the easier it is to forecast next day's price. In the last decade, different efforts have been taken to increase efficiency on the European electricity market; one of them is the Trilateral Market Coupling (TLC) launched on November 21, 2006. This market mechanism linked the

[1] The basic difference between a forward and a futures contract is that with a forward contract, a buyer and a seller agree upon a fixed price per MWh of electricity for future delivery, whereas a futures contract involves daily financial settlement using margin accounts [Fleten and Lemming, 2003].

Dutch, Belgian and French power exchanges (APX, Belpex and Powernext, respectively) and their Transmission System Operators, or TSOs (TenneT, Elia and RTE, respectively). As a result, short-term price volatility decreased and day-ahead prices converged increasingly. Before TLC market coupling there was price convergence in not even 1% of the cases; afterwards a stunning 60% was achieved. In other words, arbitrage increased significantly [De Jonghe, Meeus and Belmans, 2008].

According to Fama and French [1987], there are two leading views on commodity forward prices. The theory of storage explains the difference between the current forward price and the current spot price (i.e. the forward basis) in terms of interest foregone in storing a commodity, warehousing costs and a convenience yield on inventory. This theory was developed by Brennan [1958] and Working [1948] among others, and has proven to be non-controversial many times afterwards. There is another, more controversial theory, which defines the forward basis as the sum of an expected risk premium and an expected change in the spot price; this is called the expectations theory [Cootner (1960) and Breeden (1980), among others] . Fama and French [1987] conclude that it is hard to provide statistical evidence to end the debate concerning these two theories. This research will try to provide more evidence on forecast power and time-varying expected risk premiums of one-month, one-year and quarterly forward electricity prices of APX, Belpex and Powernext. The main goal is to study the effect of TLC market coupling on these coefficients. Next to this, skewness and variance of spot (i.e. wholesale) prices are analysed in relation to the forward risk premium; according to Bessembinder and Lemon [2002], the premium is positively related to skewness and negatively related to variance.

A dataset is constructed, consisting of daily base load spot prices and daily base load forward prices of one-month (M1) and one-year (Y1) contracts. Moreover, data on quarterly (Q) forward contract prices are collected. At first a global, graphical analysis is performed on all these variables to get an idea of their development through time. Afterwards, regression analysis is used to collect statistics on each of the variables involved; changes in the forward basis, spot prices and forward risk premium are analysed for the whole dataset. For the M1- and Y1-contracts an event study is conducted to isolate the effect of TLC market coupling on the before mentioned variables. Finally, the forward risk premium is regressed on skewness and variance.

This paper is organized as follows. Section 2 describes the theory, reviewing the existing literature on the construction of forward prices and the electricity market of Europe and of the Netherlands, Belgium and France, specifically. Section 3 discusses the methodology. Section 4 provides data. Section 5 elaborates on the results and finally, Section 6 concludes.

2 Theory

This section will provide an overview of the liberalized electricity market in Europe and its characteristics, with the emphasis on the situation in the Netherlands, Belgium and France before and after the Trilateral Market Coupling. Next to this, it will cover the most relevant theories on the pricing of forward electricity contracts.

2.1 The European electricity market

The electrification of Europe started at the end of the nineteenth century and the electrical systems and infrastructures in all European countries have evolved almost independently ever since. At the time the growth of the transmission systems reached national borders, the network could be strengthened by enabling cross-border network interconnections. In order to account for the interchanges of electricity between the different markets, specific regulation was established. All countries set out their own rules and made their own decisions. Before 1990, the electrical systems were vertically integrated and mainly controlled by national companies [Chicco, 2009].

England and Wales (April 1990) were the first countries to introduce competition in the electricity sector, followed by Norway (January 1991), Finland (June 1995) and Sweden (January 1996). These initiatives instigated other countries to introduce competition principles in their regulations, some of them tracing back to the Green Book of the European Commission in 1988. Discussions concerning the introduction of competition in the electricity sector were conducted at both the national and European Community level, all aiming at establishing common rules for the organization and operation of the electricity sector [Chicco, 2009].

The formal introduction of the electricity market liberalization came with Directive 96/92/EC on December 19, 1996, in effect since February 19, 2007 [EC, 1997]. Production, transmission, distribution and retail supply were administratively unbundled and specific rules were imposed on public service obligations. By doing so, open access to the transmission network for producers and consumers was guaranteed and incentives to the use of renewable energy resources were promoted [Chicco, 2009].

The main strategic goals of the EU concerning its internal electricity market were set out in the European Commission Strategy paper of 2004 [EC, 2004]. In this paper the creation of eight regional energy markets was envisioned: Great Britain and Ireland, the Baltic region, the Italian region, the Eastern European region, the South-Eastern Europe region, the Iberian Peninsula, the Nordic region and the

Western European region. Chicco [2009, p.15] states that the main points addressed by the Strategy paper are: "…*the development of cross-border trade, enhancement of the interconnections between the EU states, reduction of market concentration, facilitation of competitive consumer choice while delivering universal service, consistent approach to generation adequacy, support for renewable energy, removal of distortions and relations with other countries*". It is also indicated in the Strategy paper that electricity should flow between Member States as easily as it currently flows within Member States, as far as possible [EC, 2004].

2.2 The Central-West-European region

The Central-West-European (CWE) region consists out of five countries, namely, Belgium, Germany, Luxembourg, France, and the Netherlands. The "Electricity Regional Initiative" that was launched on 27 February 2006 by the European Regulators Group for Electricity and Gas (ERGEG) set out the establishment of seven Regional Energy Market projects (REMs), of which CWE is one.

Basically, the goal of this initiative is to let Belgian, German, Luxemburg, French and Dutch regulators co-operate with TSOs, market operators and market participants to increase market integration and hence foster the creation of a regional electricity market [De Jong and Giesbertz, 2008]. Not only should the regulators coordinate the effort and instigate the process, but it is also important to involve other parties such as the European Commission, member state governments and stakeholders.

On 21 November 2006, one of the most striking achievements was accomplished with the introduction of the Trilateral Market Coupling (TLC) between the Netherlands, Belgium and France. By coupling these markets, day-ahead cross border capacity could be allocated through trading on the day-ahead power exchanges. As long as day-ahead prices differ between the countries, day-ahead cross-border capacity will automatically be fully used. The success of the TLC project, largely due to the commitment of TSOs and power exchanges, also enabled the start of a power exchange in Belgium [De Jong and Giesbertz, 2008].

2.3 Basic knowledge on market coupling

Meeus et al. [2009] describe market coupling as the optimization by exchanges of the clearing of the electric energy orders submitted to their day-ahead auctions. In this way different orders introduced at different locations are exchanged as long as available network capacities allow so. Due to the verticals in the aggregated order curves, which will be further explained below, prices at these optimal exchange levels can be undetermined on an interval or price range. But in order for prices to give correct locational signals for network development, generation and consumption, it is necessary to coordinate prices between power exchanges.

The market coupling optimization problem, as referred to by Meeus et al. [2009], involves the matching of demand and supply orders of different exchanges in order to maximize total welfare gains from trading. In other words, the cheapest supply orders are linked to the most willing to pay demand orders. This does not differ much from a single market optimization problem, be it that the situation becomes more complex since orders come from different exchanges, which all represent a different network location. In order to settle the optimal solution to this problem, Meeus et al. [2009] introduce *locational marginal prices* (LMPs), which basically means that different orders of an exchange are priced such that they correspond to the shadow prices of their market clearing constraints. The following (simplified) example will try to clarify things even more.

Consider three power exchanges PX1, PX2 and PX3 to which the orders listed in Table 1 are submitted.

Table 1: Demand and supply orders introduced to PX 1 to 3

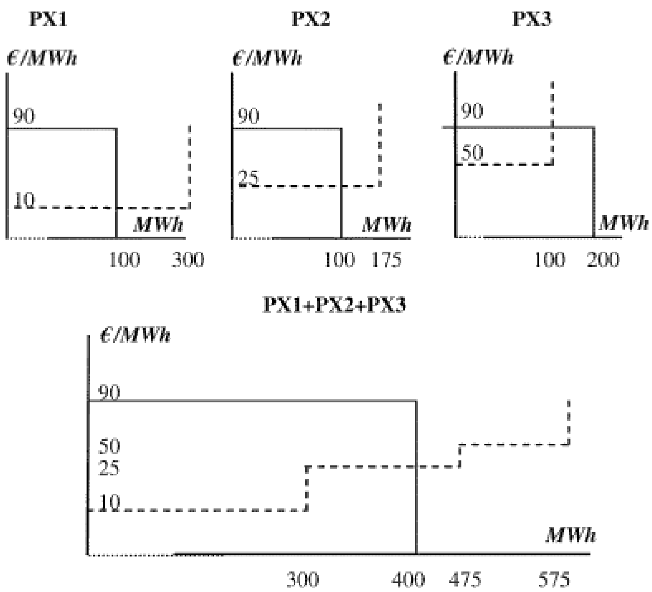
PX1	**PX2**	**PX3**
Demand orders (bids)		
100 MWh @ 90€/MWh	100 MWh @ 90€/MWh	200 MWh @ 90€/MWh
Supply orders (offers)		
300 MWh @ 10€/MWh	175 MWh @ 25€/MWh	100 MWh @ 50€/MWh

Source: Meeus et al. [2009, p. 230]

Figure 1 illustrates the implied aggregated order curves for each separate power exchange (PX) as well as for all PXs jointly. In case the PXs are not coupled, clearing volumes would be the same for all PXs (i.e. 100 MWh), but prices would range from 10, 25 and 90€/MWh for PX1, PX2 and PX3, respectively. Total gains from trading would have been 18,500€ since all power would sell at 90€/MWh ((PX1:) 100 MWh (90-10€/MWh)+(PX 2:) 100 MWh (90-25€/MWh)+(PX3:) 100 MWh (90-50€/MWh)).

In case the PXs would be coupled, but without binding network constraints, a total of 400 MWh would have been cleared at a price of 25€/MWh. In comparison with the non-coupled situation, total trading volume has increased with 100 MWh and total gains from trading have risen to 30,500€ (300 MWh (90-10€/MWh)+100 MWh (90-25€/MWh)). The difference of 12,000€ (30,500€ - 18,500€) comes from the fact that more demand can be supplied at PX3 (100 MWh (90-10€/MWh)) and besides that, the more expensive supply offer at PX3 can be replaced with the cheaper supply offer from PX1 (100 MWh (50-10€/MWh)).

Figure 1: Aggregated order curves of three PXs separately and jointly



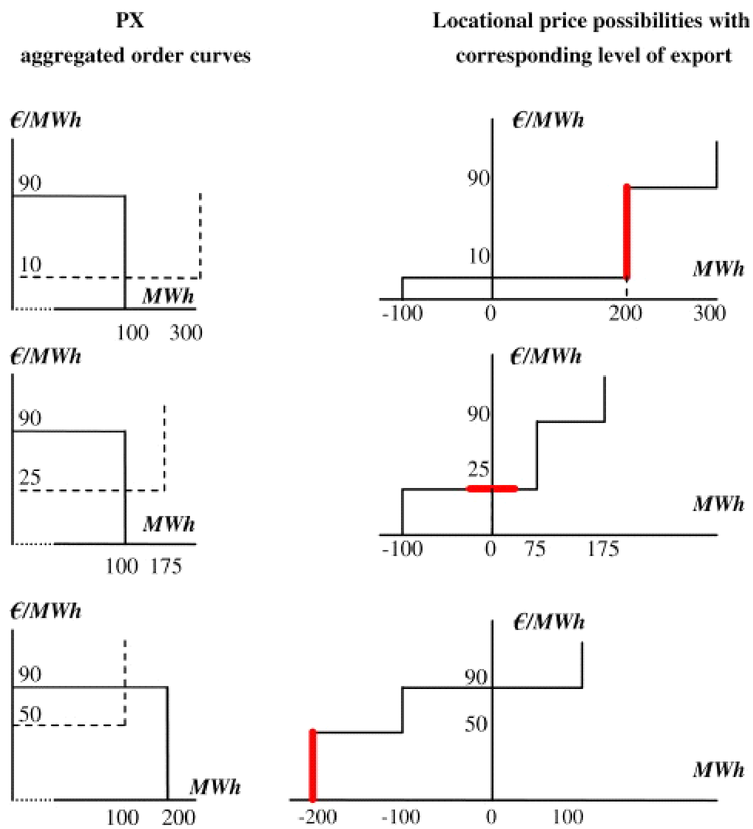
Source: Meeus et al. [2009, p. 230]

For this example the best solution to the optimization problem would be to transfer 200 MWh from PX1 to PX3, in other words to inject 200 MWh in the network at location 1 and withdraw 200 MWh at location 2. In Figure 2 locational price ranges and export levels are illustrated; these prices reflect one of the properties of LMPs, namely that every location has a single price to settle its demand and supply. Take for instance PX2:

- Supply will not be offered at a price below 25€/MWh, while at such a price level demand will absolutely want to be supplied fully. Hence, the corresponding import level for prices lower than 25€/MWh is 100 MWh.
- The maximum price demand is willing to pay is 90€/MWh. At such a high price, supply will definitely want to be supplied fully, so the export level for prices above 90€/MWh is 175 MWh.
- In between 25 and 90€/MWh demand wants to be fully supplied, while suppliers want to supply all they offered as they can make a profit. Hence, the corresponding export level for prices between 25 and 90€/MWh is 75 MWh.

- Supply and demand can be curtailed as the orders are marginally accepted at those price range, so there are several corresponding import/export levels. Figure 2 illustrates this. In other words, an export of 75 MWh corresponds to several possible locational prices at PX2.

Figure 2: Locational price ranges corresponding to the optimal solution reported in Fig. 1 as the intersection of aggregated order curves joined for the three exchanges



Source: Meeus et al. [2009, p. 231]

According to the market rules and procedures of Belpex [Belpex, 2011] that are referred to by Meeus et al. [2009], the TLC market price determination in case of price ranges is based on taking the middle price of an overlap between price ranges, subject to the LMP properties. The latter are called high level properties of the algorithm, e.g. the LMP property of having a single price per location.

2.4 Theories on pricing of forward electricity contracts

Although the modelling of power prices is quite recent in the academic literature, there exist multiple theories on the pricing of forward electricity contracts. In the following subchapters, the three most important ones will be elaborated on.

2.4.1 Fama and French [1987]

According to Fama and French [1987], there are two popular views on commodity forward prices. The first is the theory of storage, which explains the difference between current spot and forward prices in terms of forgone interest in storing a commodity, the costs of warehousing and a convenience yield on inventory. Since electricity is a non-storable commodity, we cannot use this theory for our analysis. However, we can use the alternative view, which splits a forward price into an expected risk premium and a forecast of a future spot price.

Huisman and Kilic [2010] state that following this so-called expectations theory of Fama and French [1987], forward prices for non-storable commodities contain information about the expectation of market participants of the (average) spot price in the delivery period, and also a risk premium which compensates producers for the uncertainty involved in committing to sell against fixed prices. This is the consensus view on electricity forward prices, which we will adapt to analyse our data. Hence, we also use the natural logarithms of electricity prices in our regressions.

Let $F(t\ ,T)$ denote the forward price per MWh at time t implying the delivery of 1MW of electricity in each hour of the delivery period T ($t < T$). $S(t)$ is the day-ahead price per MWh quoted on day t for delivering 1MW of electricity in each hour of the day t+1. The forecast of the future spot price is given by $E_t[S(T)]$ which is equal to the expectation at t of the average day-ahead price during the future delivery period T. Finally, $E_t[P(t,T)]$ denotes the expected risk premium per MWh for delivery of electricity in period T, quoted at time t.

According to the expectations theory, the forward price quoted at time t consists of an expected risk premium as well as a forecast of a future spot price. In formula:

$$F(t, T) = E_t[S(T)] + E_t[P(t, T)] \tag{1}$$

After subtracting the current spot price from both sides of the equation, Fama and French [1987] end up with the following equation:

$$F(t, T) - S(t) = E_t[P(t, T)] + E_t[S(T) - S(t)] \tag{2}$$

Moreover, equation (1) can be rewritten as follows, indicating that the difference between the forward price and the forecast of the future spot price is equal to the expected risk premium:

$$E_t[P(t, T)] = F(t, T) - E_t[S(T)] \tag{3}$$

Now, substituting equation (3) into (2) gives us the forward basis [$F(t, T) - S(t)$], which contains information about the expected change in the spot price between t and T and the expected to be realized risk premium:

$$F(t, T) - S(t) = E_t[S(T) - S(t)] + F(t, T) - E_t[S(T)] \tag{4}$$

To investigate whether the expected premium in (4) is nonzero or whether forward prices have power to forecast future spot prices, we use two regressions on the observed basis which were proposed by Fama [1984], namely a spot price change and risk premium regression:

$$S(T) - S(t) = \alpha_1 + \beta_1[F(t, T) - S(t)] + \sigma_1\epsilon_{1,t} \tag{5}$$

and

$$F(t, T) - S(T) = \alpha_1 + \beta_2[F(t, T) - S(t)] + \sigma_2\epsilon_{2,t} \tag{6}$$

These regressions are subject to an adding-up constraint; the sum of the spot price change and the premium is the forward basis, [$F(t, T) - S(t)$]. Consequently, both the sum of the intercepts as well as the sum of residuals must be 0.0. But most importantly, summing up the coefficients β_1 and β_2 must result in 1.0; put differently, all variation in the basis is always allocated to the expected premium, the expected change in the spot price, or a certain mix of the two.

If β_1 is positive and significantly different from zero, this means that the basis observed at t contains information about the change in the spot price between t and T. In other words, the forward price has forecasting power with respect to the future spot price.

If β_2 turns out to be positive and significantly different from zero, the basis observed at t contains information about the eventually realized premium at T. This can be interpreted as evidence of time-varying expected premiums.

2.4.2 Bessembinder and Lemon [2002]

Bessembinder and Lemon [2002] use an equilibrium approach, which relies on two assumptions. First, prices are supposed to be determined by industry participants rather than outside speculators. Second, power companies are concerned with both the mean and variance of their profits. According to their model, the forward risk premium is a function of the difference between two covariance terms, which are related to the variance and skewness of spot (i.e. wholesale) power prices. Moreover, marginal production costs may increase steeply with output and aggregate demand is assumed to be exogenous and stochastic. They state that the forward price minus the expected spot price, i.e. the forward premium, is positively (resp. negatively) related to the skewness (resp. variance) of the spot price. Price spikes, caused by sudden positive shocks in electricity demand, contribute to skewness; demand for forward contracts increases as retailers face price spikes, hence the forward premium will be higher. When variance increases, the net downside risk of the retailer decreases, which lowers the demand for forward contracts and thus the premium.

The fact that the no-arbitrage approach to pricing derivative securities cannot be applied in the electricity market, because of the non-storability of this commodity, triggered their research. Normally, spot and forward prices are linked as a no-arbitrage condition by the well-known cost-of-carry relationship. However, this involves buying the asset at the spot price and storing it for subsequent sale at the forward price. Since power cannot be stored, electricity forward prices need not conform to the cost-of-carry relationship.

Moreover, according to their research, forward market positions of power producers depend on forecast output and the skewness of power demand. Meanwhile, power retailers position themselves depending on forecast usage and the interaction between load and system demand as measured by power demand betas.

They develop a model which makes the following testable hypotheses regarding the forward premium, we quote [Bessembinder and Lemon (2002), p. 1362]:

- Hypothesis 1: *The equilibrium forward premium decreases in the anticipated variance of wholesale prices, ceteris paribus.*

- Hypothesis 2: *The equilibrium forward premium increases in the anticipated skewness of wholesale prices, ceteris paribus.*

- Hypothesis 3: *The equilibrium forward premium is convex, initially decreasing and then increasing, in the variability of power demand, ceteris paribus.*

- Hypothesis 4: *The equilibrium forward premium increases in expected power demand, ceteris paribus.*

Next to this, they formulate several predictions about the distribution of forward and spot prices. First, they state that the equilibrium premium in forward prices will probably vary in sign and magnitude, on a seasonal and geographical basis. Second, they predict that the probability distribution of spot power prices will be characterized by lower mean demand, relatively low volatility and low skewness, during the temperate climates of spring and fall. On the contrary, demand, variability and skewness will be higher during winter and summer. Finally, the model predicts higher forward and average spot prices in geographic regions where the power system is on average close to system capacity.

In 2002, when Bessembinder and Lemon published their research on electricity prices and premiums, they recognized the fact that power markets were new and data was scarce. Hence, empirical testing of the hypotheses developed above was constrained. Nowadays, more data is available, so it might be interesting to have a new, thorough look at their findings. Unfortunately, we do not have collected data on power demand; therefore we cannot test hypotheses 3 and 4, stated above. However, since we do have data on the forward premium, variance and skewness, we will use both graphical and regression analysis to test hypotheses 1 and 2.

2.4.3 Cartea and Villaplana [2008]

Cartea and Villaplana [2008] propose a model in which two state variables, demand and capacity, are the main determinants of wholesale electricity prices. They undertake an empirical analysis of the PJM market, derive valuation formulae for forward contracts and use the possibility of jumps in the short-term process of the Schwartz and Smith [2000] model. According to their research, volatility of demand is seasonal and the market price of demand risk is also seasonal and positive. As a result, the price of forward contracts is (seasonally) driven up. In all markets they find that the forward premium exhibits a seasonal pattern. Forward contracts trade at a premium during months of high volatility of demand, while they can either trade at a relatively small or even negative premium during months of low volatility of demand.

Again, we do not have data on power demand, nor do we have data on capacity. Thus, the findings of Cartea and Villaplana [2008] cannot be tested in this research paper. But by graphically analysing collected price data on quarterly base load electricity forward contracts, we will test if forward risk premiums are indeed higher during summer and winter than they are during spring and fall. Moreover, we investigate the differences in evidence for forecast power and time-varying risk premiums between these various seasons of electricity delivery.

3 Methodology

The main goal of this research is to examine to what extent the TLC market coupling affected base load electricity spot and forward prices on the Dutch, Belgian and French power exchanges (APX, Belpex and Powernext, respectively) and arising from this, its effect on the forward basis, the expected change in the spot price and the expected risk premium. Next to this, the effect of TLC market coupling on the forecast power and expected premiums of quarterly forward contracts is subject of study.

We start off with a graphical analysis of the development of electricity spot prices and one-month, one-year and quarterly forward prices for APX, Belpex and Powernext. Hereafter, we examine the effects of TLC market coupling on the forward basis and the information therein, by analysing collected data on daily averages of base load spot and forward prices between the years 2004 and 2011. For this analysis, we follow the theory and methodology of Fama and French [1987] (go back to section 2.4.1 of this paper for a more thorough explanation on all mechanisms involved). Regressions (5) and (6), the spot price change and risk premium regressions, are of utmost importance for our analysis:

$$S(T) - S(t) = \alpha_1 + \beta_1[F(t, T) - S(t)] + \sigma_1\epsilon_{1,t} \tag{5}$$

and

$$F(t, T) - S(T) = \alpha_1 + \beta_2[F(t, T) - S(t)] + \sigma_2\epsilon_{2,t} \tag{6}$$

We are looking at three different forward contracts, all delivering an amount of 1 MWh of electricity during each day of the delivery period, against a fixed price. First, one-month forward contracts (M1) imply the delivery of electricity during the upcoming month. Second, one-year forward contracts (Y1) deliver electricity during the upcoming year. Third, quarterly forward contracts imply the delivery of electricity in upcoming quarters of a year. Hence, both regressions will be run three times. For the M1-analysis, $S(t)$ is the current spot price at time t, and $S(T)$ is the average spot price during the month of delivery. Furthermore, $F(t, T)$ is simply the price of the M1-forward contract at time t. For the Y1-analysis, the same approach is being used, but $S(T)$ is the average spot price during the year of delivery. Finally, $S(T)$ is the average spot price during each delivery quarter for the quarterly contract analysis.

At first, regressions (5) and (6) are performed for the whole dataset, in order to get global statistics for all three power exchanges. But for the purpose of isolating the TLC market coupling effect on electricity prices, we run both regressions again, globally following event study methodology [Binder, 1998]. The market coupling, taking place on November 21, 2006 is the *event*. Around this event we estimate an *event window*; this is the time period in which electricity prices can be directly influenced by the (announcement of the) event. Our event window will be from t = -5 to t = +5; from five days prior to the market coupling at t = 0, to five days after. Prior to t = -5, an *estimation window* can be formed to estimate model parameters. This estimation window is excluded from the event window to prevent parameters from being biased by the event. Finally, the period after t = +5 is called the *post-event window*; it is similar in length to the estimation window, in order to optimize the comparison of conditions between the period before and after TLC market coupling.

Besides this regression analysis which is mainly based on Fama and French [1987], we also regress the forward risk premium on the skewness and variance of electricity spot prices in order to test the statements made by Bessembinder and Lemon [2002]. The following regressions will be run for all one-month and one-year forward contracts:

$$F(t, T) - S(T) = \alpha_1 + \upsilon \text{ (var)} + \varepsilon$$

and

$$F(t, T) - S(T) = \alpha_1 + \gamma \text{ (skew)} + \varepsilon$$

where $F(t, T) - S(T)$ equals the forward risk premium, i.e. the current forward price minus the average spot price during the delivery period. If hypotheses 1 and 2 of Bessembinder and Lemon [2002] are correct, γ will turn out to be positive and υ negative, for all forward contracts. In other words, the risk premium will be positively related to the skewness and negatively related to the variance of wholesale prices.

4 Data

The main dataset for this study consists of daily average base load electricity spot and forward prices for three markets: the Amsterdam Power Exchange (APX), the Belgian Power Exchange (Belpex) and the French Power Exchange (Powernext). The forward contracts include base load forward contracts for a period of one month (M1), one year (Y1) and one quarter (Q1-Q4), respectively.

The time range of the datasets for the APX, Belpex and Powernext spot, M1- and Y1-forward prices differs in length; we collected as many prices as we could find in the Bloomberg Financial Database. Our dataset for the APX consists of a total of 1688 observations, starting on the 5th of January, 2005 and ending on the 8th of November, 2011. For Belpex, the first observation is on the 7th of September, 2004 and the last on the 13th of December, 2011 making for a total of 1604 observations. Before November 2006 Belgium had no organized power market, but Electrabel published the Belgian Power Index (BPI), allowing participants to buy and sell day-ahead base load power in blocks [Huisman and Kilic, 2010]. Finally, the dataset for Powernext (France) consists of a total of 1558 observations, starting on the 8th of June, 2005 and ending on the 8th of November, 2011.

When it comes to quarterly forward contract data, time ranges also differ per power exchange. In the Bloomberg Financial Database, the ticker symbols 'ELHBQ106', 'ELBBQ106' and 'ELFBQ106' denote the base load electricity forward contracts for delivery in the first quarter of the year 2006 for the Netherlands, Belgium and France, respectively. Our overall range is largest when for every contract, we stick to the last 107 price observations before the start of the delivery period. This leaves us with the following quarterly data: for APX we have data on Q404 to Q408, for Belpex Q405 to Q408 and for Powernext Q106 to Q409. For all clarity, Q404 equals the fourth quarter of the year 2004, Q106 the first quarter of 2006, and so on.

At first, regressions (5) and (6) are performed on all available data, in order to collect (global) statistics for all three power exchanges. Afterwards, following the rules of econometric engagement, the datasets are cut into two similar time spans for each power exchange respectively, one period before and one period after the TLC market coupling. These so-called 'pre' and 'post' periods are part of event study methodology and are very useful in isolating the effect of TLC market coupling on base load spot and forward electricity prices. For the APX we have a total of 668 pre- as well as post-observations; for Belpex a total of 505 pre- and post-observations; for Powernext a total of 359 pre- and post-observations.

5 Results

As stated in section 2.4 of this research paper, there exist multiple theories on the pricing of forward electricity contracts. We elaborated on the three most important ones, i.e. Fama and French [1987], Bessembinder and Lemon [2002] and Cartea and Villaplana [2008]. The first paper, Fama and French [1987], is of utmost importance for our analysis; we mainly follow their rules of conduct for our regression analysis and their interpretation of results. By looking at the skewness and variance of electricity prices in comparison with the forward risk premium, we test the statements made by

Bessembinder and Lemon [2002]. Unfortunately, we do not have collected data on demand and capacity, thus we cannot elaborate on that specific part of their research, nor can we test the statements made by Cartea and Villaplana [2008].

This section is divided into two parts: in the first part we elaborate on the results of graphical analysis, in the second on the results of regression analysis.

5.1 Graphical analysis

In the following subchapters we will graph the development of electricity spot and forward prices, of skewness and variance in relation to the forward risk premium and of quarterly forward contracts.

5.1.1 Development of electricity spot and forward prices

First of all, we simply want to see if there is a stabilizing effect on spot and forward prices, since one of our hypotheses is that market coupling will make spot prices less volatile, hence decreasing the risk of significant price spikes. Intuitively, one would expect forward prices to also become more stable because of this, since forward contracts are a way of hedging against the price risk involved in the highly volatile spot market. To study the legitimacy of these statements, we start off by graphing price movements over time for each power exchange separately. Each graph shows the amount of Euros paid on the vertical axis and the date on the horizontal axis.

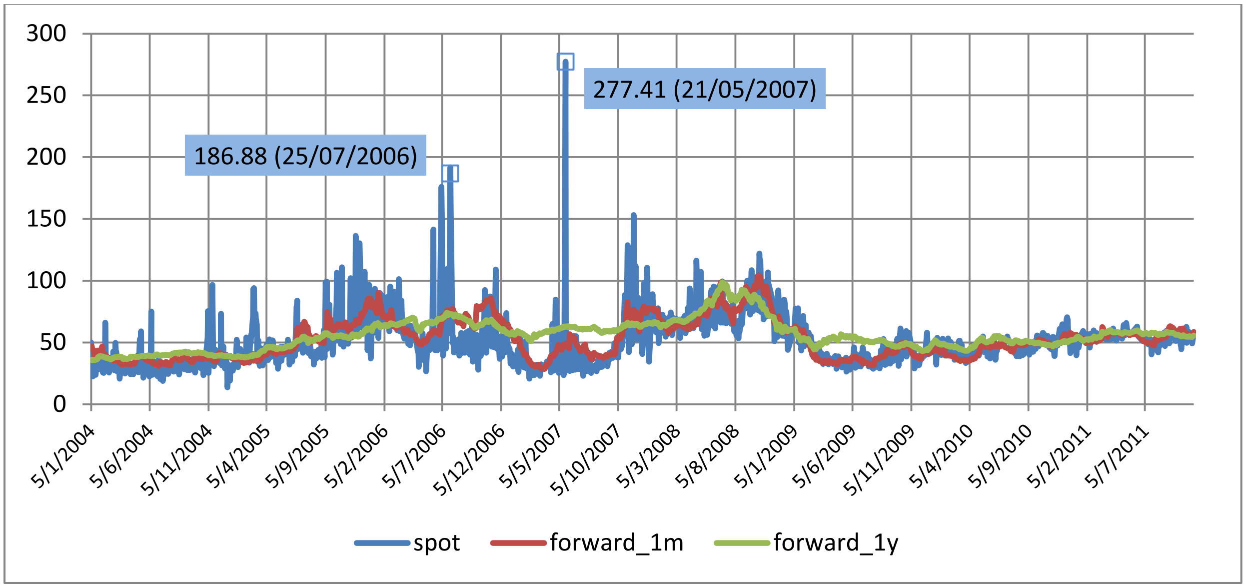
By looking at Graph 1.1 we can see that from the beginning of 2007 on, spot prices on APX show a slightly less volatile picture than before; there are fewer price spikes than during the years 2004 to 2006. Both the M1- and Y1-forward contract prices do not seem to show any significant changes in overall volatility. From the start of 2009 onwards, all prices show a remarkably stable development.

Graph 1.2 shows the development of spot and forward prices for Belpex. After TLC market coupling the overall volatility of spot prices seems to have decreased, but there are two significant price spikes on the 21st of May and the 15th of November 2007. These can be caused by unexpected shortage of electricity supply, unexpected increase in demand, or a combination of the two. From the beginning of 2008 onwards, both spot and forward prices show a clearly more stable development.

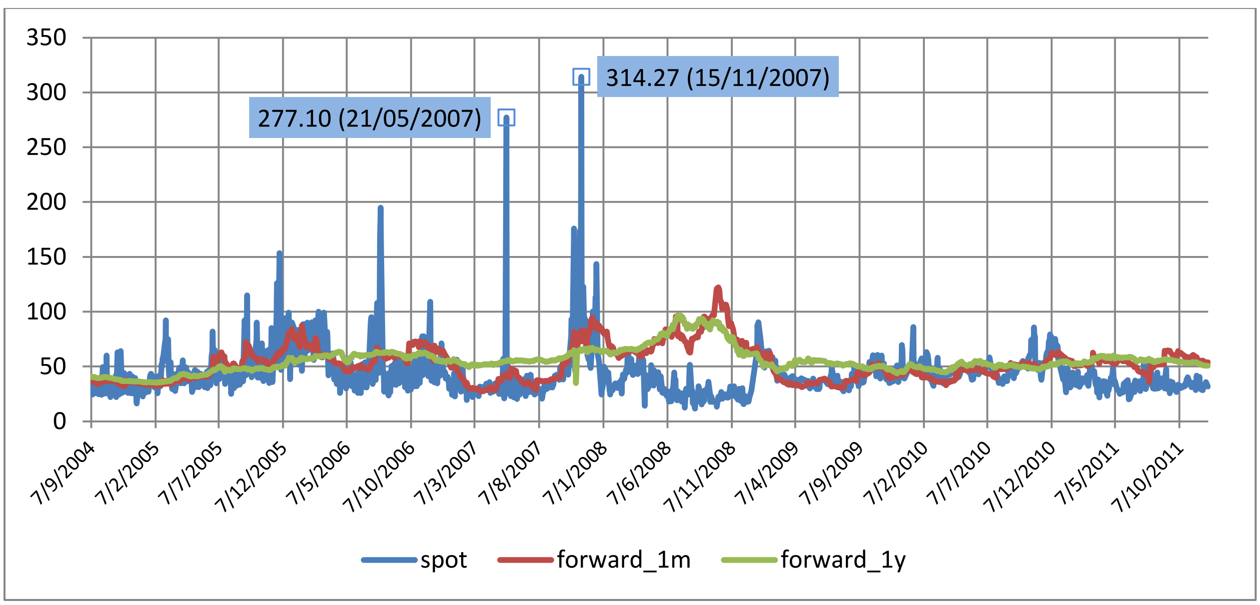
Finally, the development of spot and forward prices on Powernext is plotted in Graph 1.3. After TLC market coupling took place, all prices seem to show a more stable pattern during 2007. But at the end of 2007 there is a sudden increase in spot price volatility. Apart from one big spike of the spot price on the

19th of October 2009, spot as well as forward prices seem to show a more stable pattern from the beginning of 2008 onwards; spot as well as forward prices no longer exceed 100 euros per MWh.

Graph 1.1 : Development of electricity spot, one-month forward and one-year forward prices for the APX market (5 January 2004 – 8 November 2011)

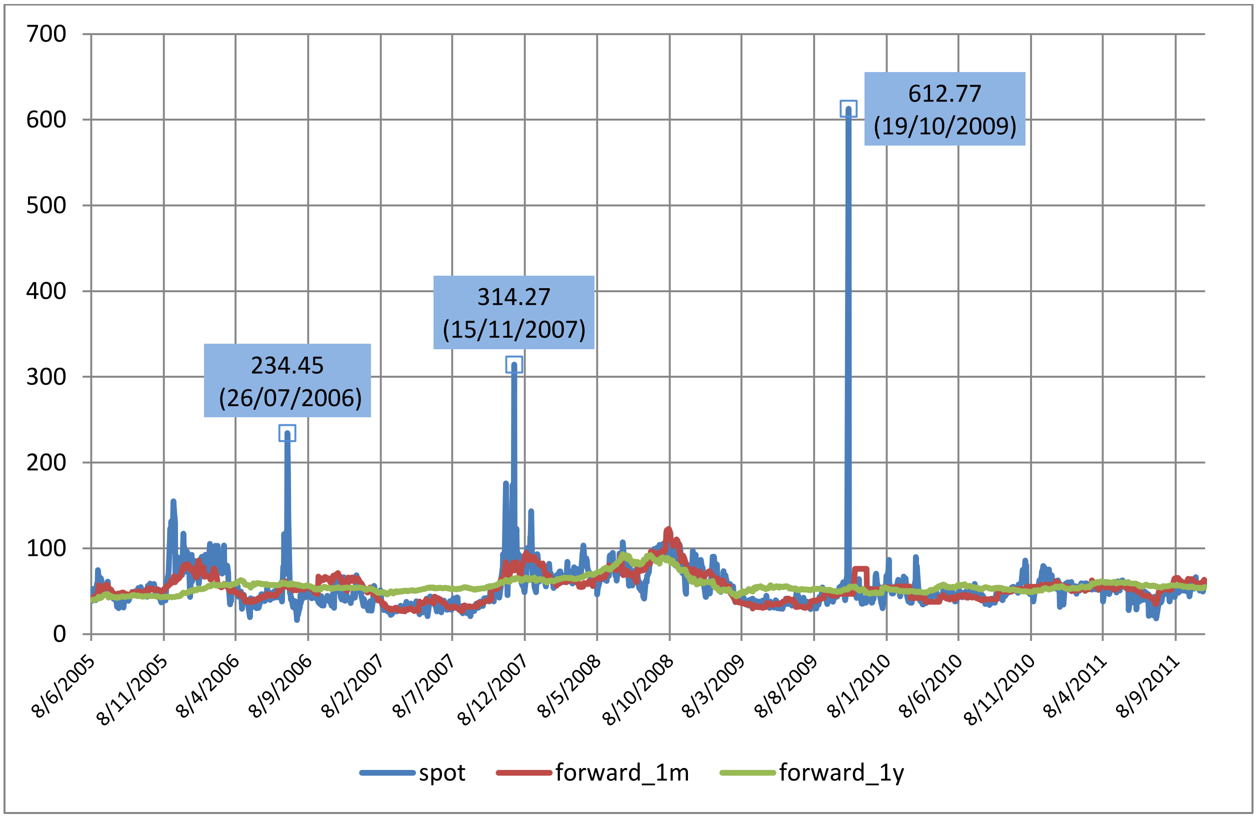


Graph 1.2 : Development of electricity spot, one-month forward and one-year forward prices for the Belpex market (7 September 2004 – 13 December 2011)



Summarizing, we can state that volatility of both spot and forward prices indeed seems to have decreased in the years after TLC market coupling on November 21, 2006.

Graph 1.3 : Development of electricity spot, one-month forward and one-year forward prices for the Powernext market (8 June 2005 – 8 November 2011)



5.1.2 Skewness and variance in relation to the forward risk premium

In their study, Bessembinder and Lemon [2002, p. 1362] make a total of four testable hypotheses. Since we do not have collected data on power demand, this research will focus on their first two hypotheses:

- Hypothesis 1: *The equilibrium forward premium decreases in the anticipated variance of wholesale prices, ceteris paribus.*

- Hypothesis 2: *The equilibrium forward premium increases in the anticipated skewness of wholesale prices, ceteris paribus.*

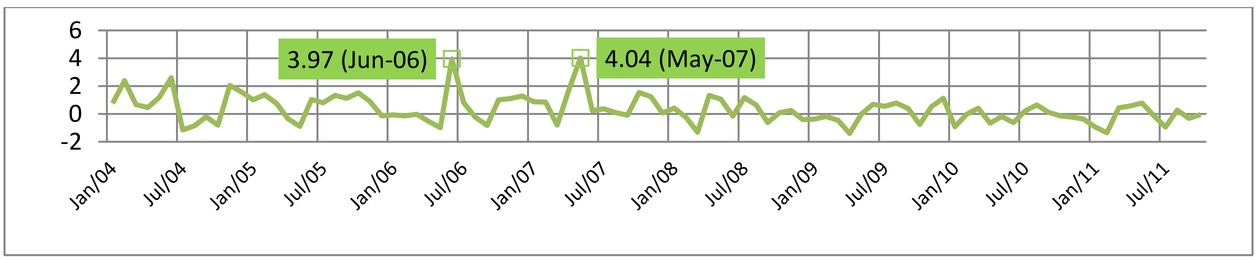
The logic behind these hypotheses is as follows: an increase in variance lowers the downside risk of the investments made by retailers, because there will be more spread in observed spot prices. This should cause a decrease in the forward risk premium. An increase in skewness means that the risk of spot price spikes is higher, hence there will be more demand for forward contracts by electricity retailers in order to hedge against this expected increase in future spot prices, thus an increase in the forward risk premium.

Skewness, variance and risk premium values are calculated and graphed for all three markets. The hypotheses stated above will be tested by comparing the skewness and variance graphs with the risk premium graph; section 5.2.4 will also elaborate on the results of regressing the forward premium on both skewness and variance. Each market is being analysed separately.

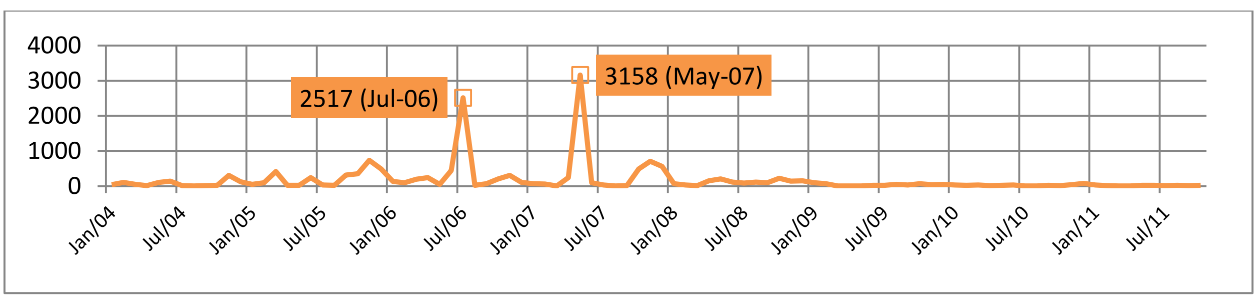
5.1.2.a APX

Graph 2.1 and 2.2 below plot the skewness and variance of APX electricity spot (or wholesale) prices, respectively. When comparing these graphs, one can immediately notice two large spikes taking place at approximately the same time. These spikes are marked in the graphs along with their maximum values and dates; the same will be done for the Belpex and Powernext markets. Next to this, Graph 2.3 plots the one-month and one-year risk premiums of the APX market for all available data.

Graph 2.1 : Skewness of APX wholesale prices (January 2004 – November 2011)

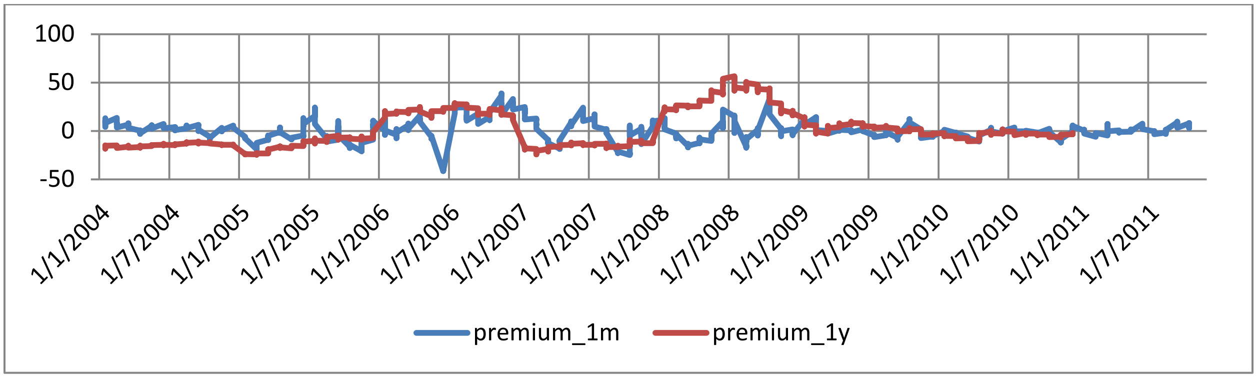


Graph 2.2 : Variance of APX wholesale prices (January 2004 – November 2011)



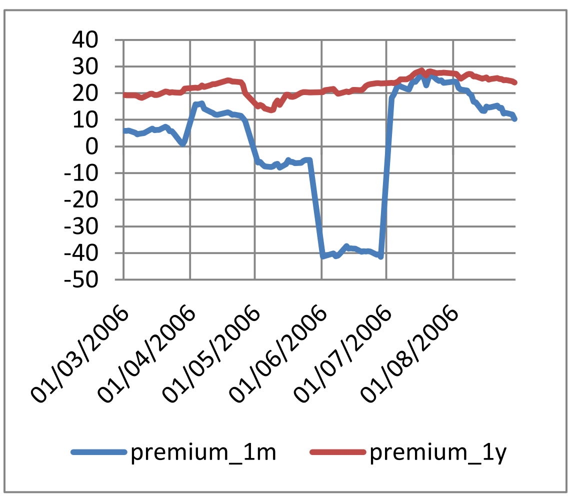
As one can see in Graph 2.1 and 2.2, the months of June 2006 and May 2007 show high skewness and the months of July 2006 and May 2007 show high variance. Let us now zoom in on the relevant time periods with respect to the forward risk premium; Graphs 2.4 and 2.5 plot the development of the risk premium between March and September 2006 and between March and July 2007. The one-year forward risk premium does not seem to show any significant reaction to both changes in skewness and variance of wholesale prices; the one-month risk premium on the contrary shows a more volatile picture. As skewness and variance increase sharply between March and June 2006 and March and July 2006, respectively, the

Graph 2.3 : Risk premiums of the APX market (January 2004 – November 2011)

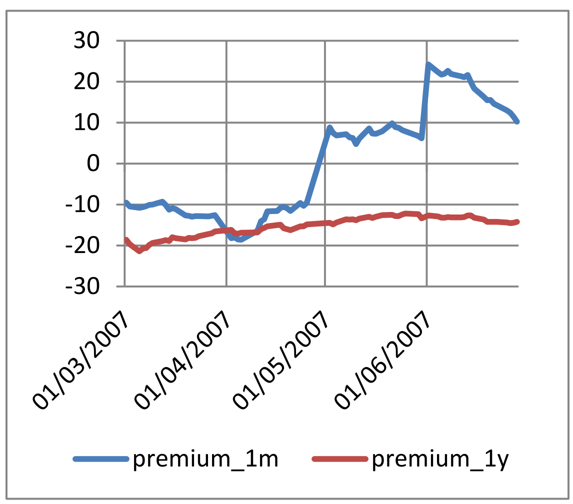


M1-risk premium shows a sharp decline. When skewness is at its highest level during June 2006, the M1-premium is at its lowest level; when variance is at its highest level during July 2006, the M1-premium is at its highest level as well. In the other period of high skewness and variance, between March and May 2007, the M1-premium increases in the anticipated skewness and variance of wholesale prices. Hence for the first period of high skewness and variance, the statements made by Bessembinder and Lemon [2002[] are contradicted for the M1-forward contracts. This is also the case during the second period, where the M1-premium indeed seems to increase in the anticipated skewness of spot prices, but also increases in the anticipated variance.

Graph 2.4 : Development of M1- and Y1-premiums for APX between March and September 2006



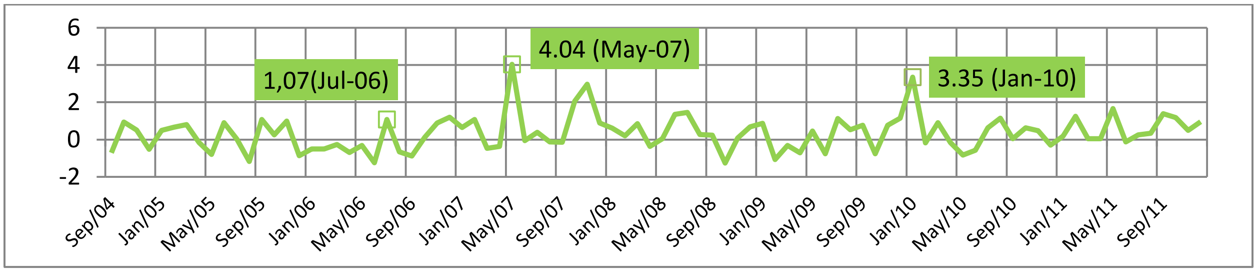
Graph 2.5 : Development of M1- and Y1-premiums for APX between March and July 2007



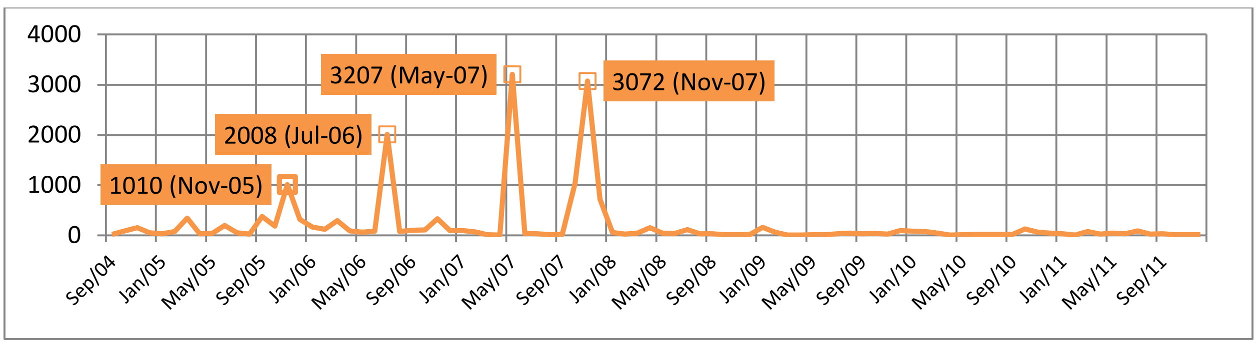
5.1.2.b Belpex

Below the developments of skewness, variance and risk premiums are plotted for Belpex (Graphs 3.1 to 3.3). One can immediately see that again, skewness and variance of wholesale prices do not seem to influence the risk premium of one-year forward contracts. Let us zoom in on the risk premium development during the periods of June to August 2006 and of March to July 2007, to get a closer look at the reaction of the M1-premium to the sharp increases in both skewness and variance which are highlighted in Graph 3.1 and 3.2.

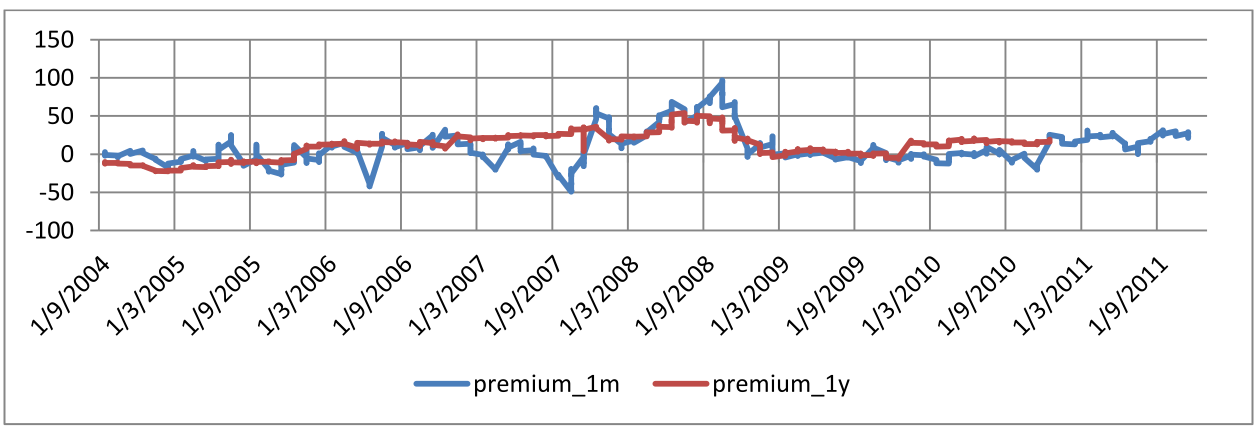
Graph 3.1 : Skewness of Belpex wholesale prices (September 2004 – December 2011)



Graph 3.2 : Variance of Belpex wholesale prices (September 2004 – December 2011)

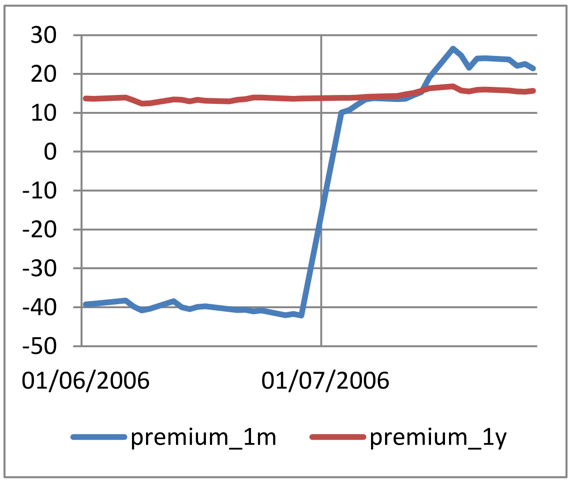


Graph 3.3 : Risk premiums of Belpex wholesale prices (September 2004- December 2011)

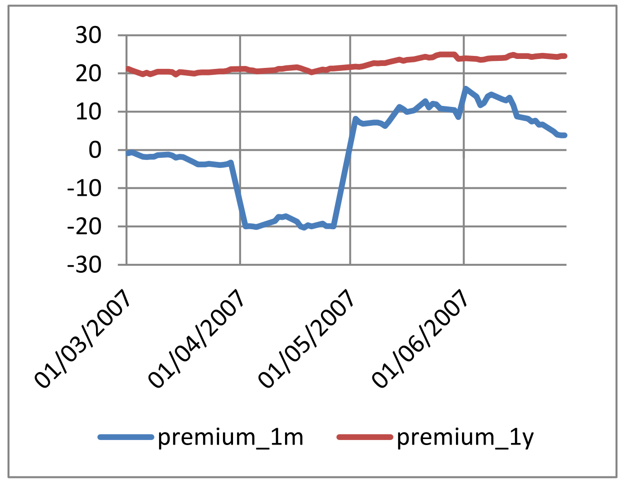


As one can see in Graph 3.4 below, the M1-risk premium increases sharply in July 2006 as a reaction to significant increases in skewness and variance. The same thing happens in May 2007 (Graph 3.5), where the sharp increases in skewness and variance seem to have a significant increasing effect on the M1-premium. Hence, the risk premium for one-month forward contracts indeed seems to increase in the anticipated skewness of spot prices; it does not decrease in the anticipated variance.

Graph 3.4 : Development of M1- and Y1-premiums for Belpex between June and August 2006



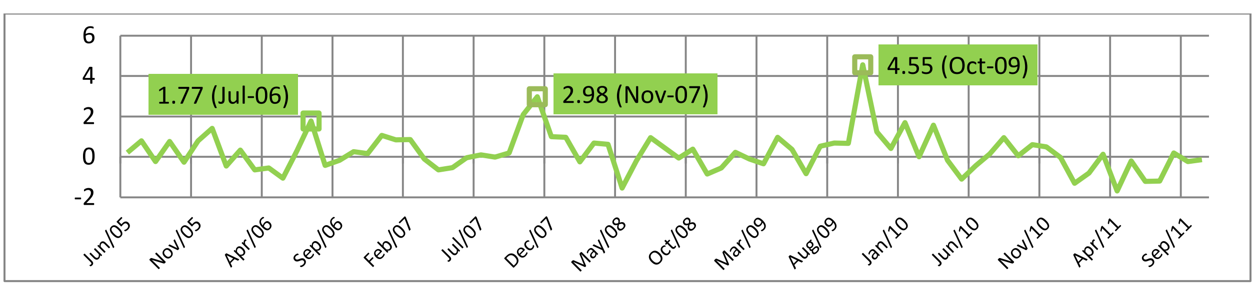
Graph 3.5 : Development of M1- and Y1-premiums for Belpex between March and July 2007



5.1.2.c Powernext

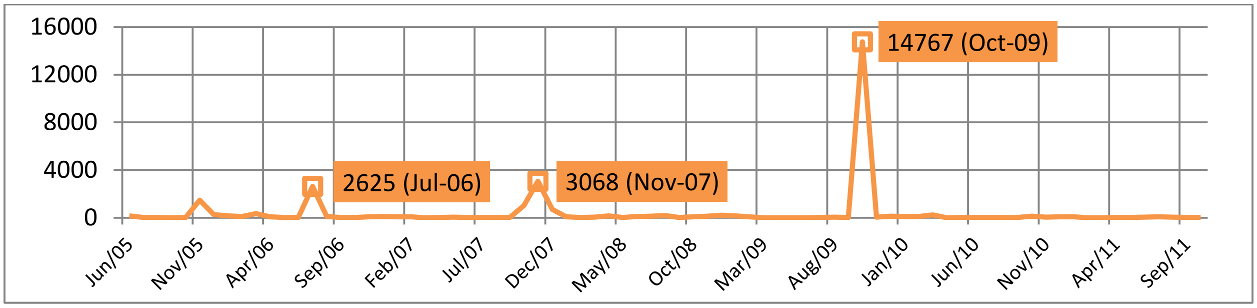
Finally, let us have a look at the French power exchange, Powernext. In Graph 4.1 and 4.2, both skewness and variance show spikes that reach maximum values during July 2006, November 2007 and October 2009. Again, skewness and variance do not seem to have any significant impact on the development of the one-year risk premium.

Graph 4.1 : Skewness of Powernext wholesale prices (June 2005 – October 2011)

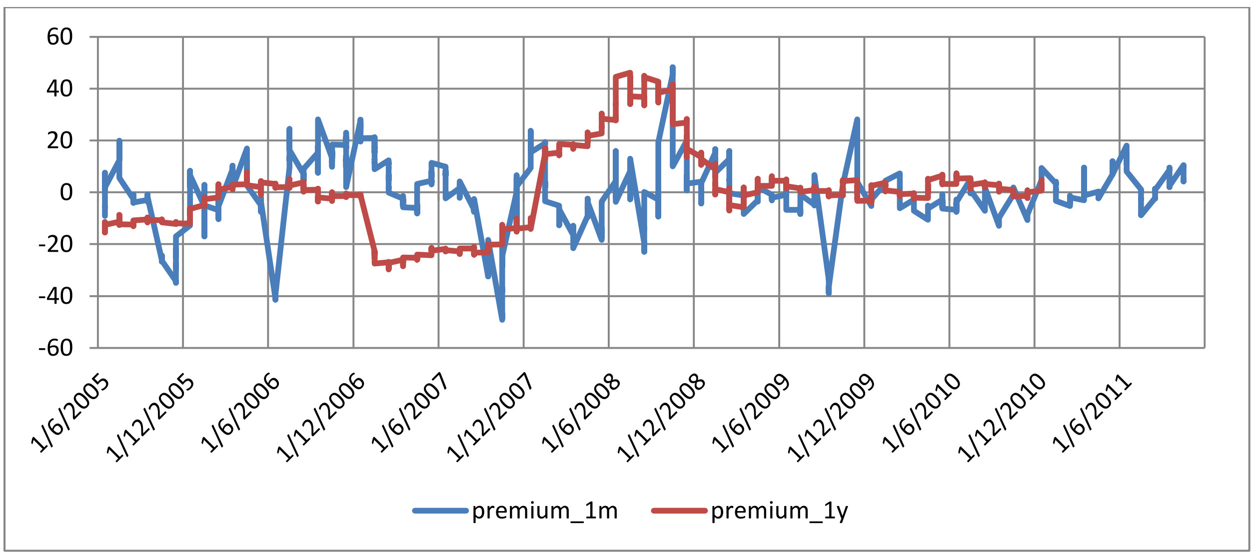


One can see in Graph 4.4 that during July 2006 the M1-premium sharply increases, while both skewness and variance are at a maximum spike level as well. Graph 4.5 shows that the same holds for the period between October and November 2007, where both skewness and variance reach a new high and the M1-premium increases significantly. Last but not least, the third spikes in skewness and variance during October 2009 seem to have a clearly increasing effect on the M1-premium development (Graph 4.3). Hence, the M1-premium indeed seems to increase in the anticipated skewness of wholesale prices, but does not decrease in the anticipated variance.

Graph 4.2 : Variance of Powernext wholesale prices (June 2005 – October 2011)

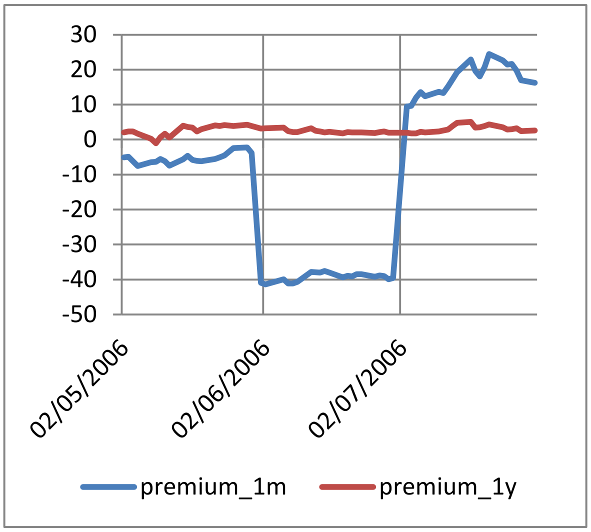


Graph 4.3 : Risk premiums of the Powernext market (June 2005 – September 2011)

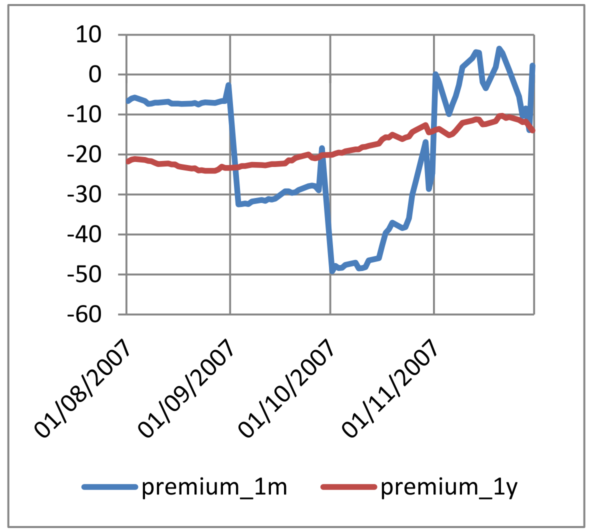


Summarizing, skewness of spot prices indeed seems to have an increasing effect on the one-month forward risk premiums on all three power exchanges; it does not seem to have any influence on the one-year risk premiums. Variance seems to have an increasing effect on the one-month risk premiums as well, where it also does not seem to affect one-year premiums. Since Bessembinder and Lemon [2002] state that variance should have a decreasing effect on the risk premium, we will use regression analysis to test our graphical findings; results are elaborated on in section 5.2.4 of this paper.

Graph 4.4 : Development of M1- and Y1-premiums between May and August 2006



Graph 4.5 : Development of M1- and Y1-premiums between August and December 2007



5.1.3 Quarterly forward electricity contracts

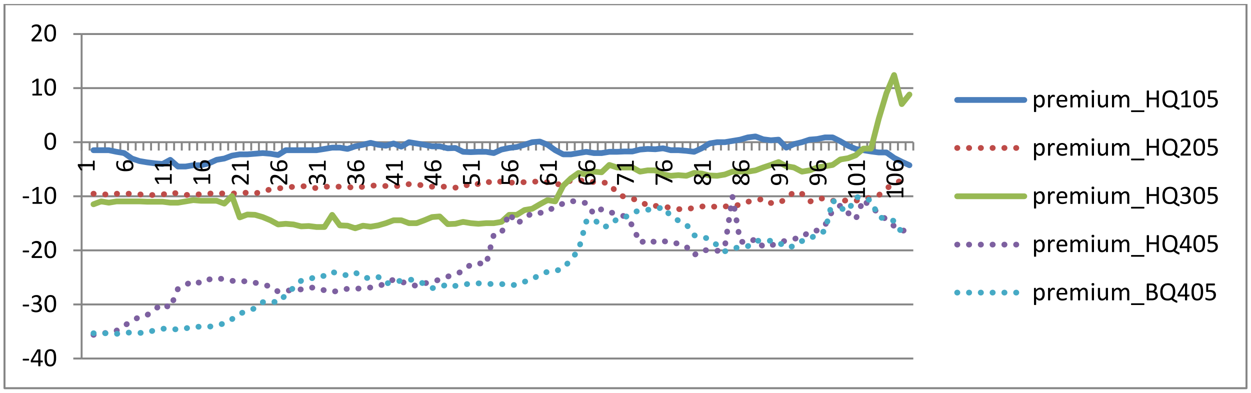
Finally, we will try to graphically analyse the development of the forward risk premiums of quarterly forward contracts during different years of power trading on APX, Belpex and Powernext. Cartea and Villaplana [2008] state that forward risk premiums should be higher during the seasons of winter (Q1) and summer (Q3). Logically, one would expect risk premiums of contracts implying the delivery of electricity in these seasons to also be higher than those of the Q2- and Q4-contracts.

Graph 5.1 shows the premiums for all contracts implying delivery of electricity in the four quarters of 2005; premiums are substantially lower for delivery of electricity during the fourth quarter of the year, for both APX and Belpex. The last 40 observations for delivery in the second quarter in the Netherlands show the same picture; the premiums for delivery in the first and third quarter are largely negative and close to zero, but mostly higher than all other risk premiums.

By looking at Graph 5.2 one can see that for all markets, the risk premiums in 2006 show the opposite picture; contracts implying the delivery of electricity in the second and fourth quarter of the year have mostly positive premiums, compared to negative premiums for the contracts delivering in the first and third quarter of 2006. Especially the Q4-contracts stand out, which have premiums all remarkably higher than those of the Q1- and Q3-contracts.

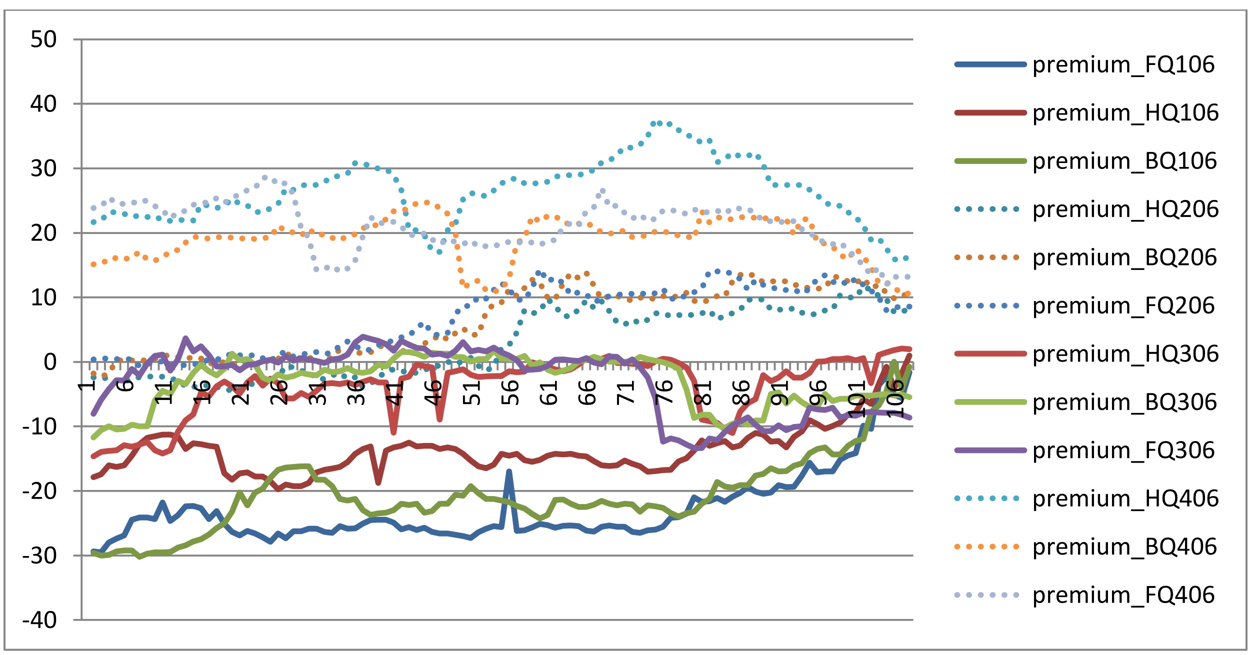
In 2007 (Graph 5.3), the first year after market coupling, contracts implying delivery in the fourth quarter of the year have substantially lower (and negative) premiums than all other quarterly contracts. The Q1-contracts now carry the largest positive premiums, followed by the Q3-contracts.

Graph 5.1 : Last 107 price observations per quarterly forward contract for the year 2005

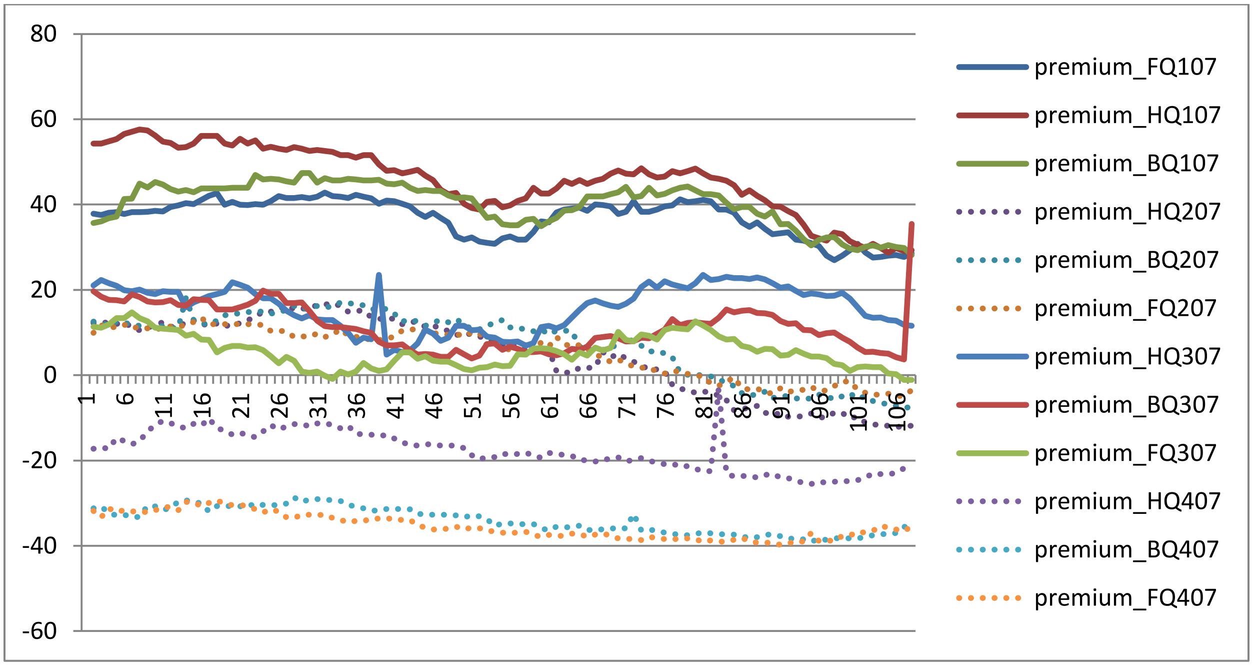


When looking at the year 2008 (Graph 5.4), one can immediately see that Belpex has the largest, positive risk premiums for all quarterly forward contracts. The Q4- and Q3-contracts have the largest premiums, followed by the Q1-contract and the Q2-contract. The four contracts with the lowest and negative premiums are those implying the delivery in the second and third quarter in the Netherlands and France. Contracts delivering electricity during the first and fourth quarter of 2008 in these countries have premiums fluctuating between 0 and 20 euros, mostly.

Graph 5.2 : Last 107 price observations per quarterly forward contract for the year 2006

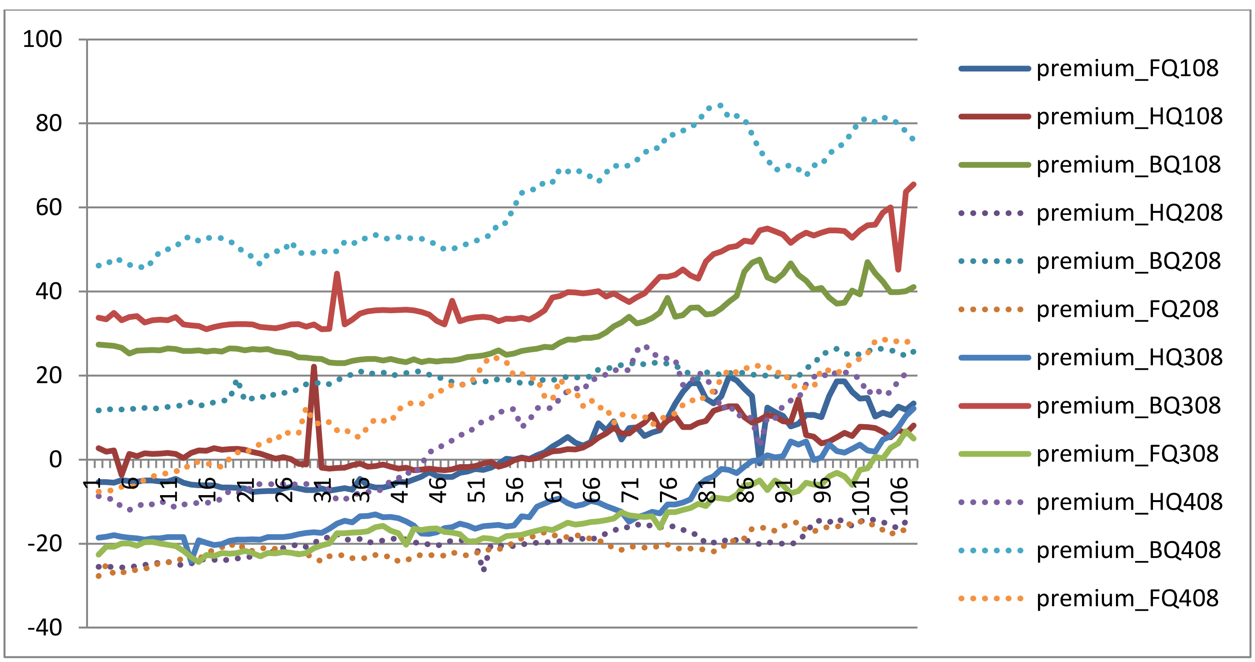


Graph 5.3 : Last 107 price observations per quarterly forward contract for the year 2007

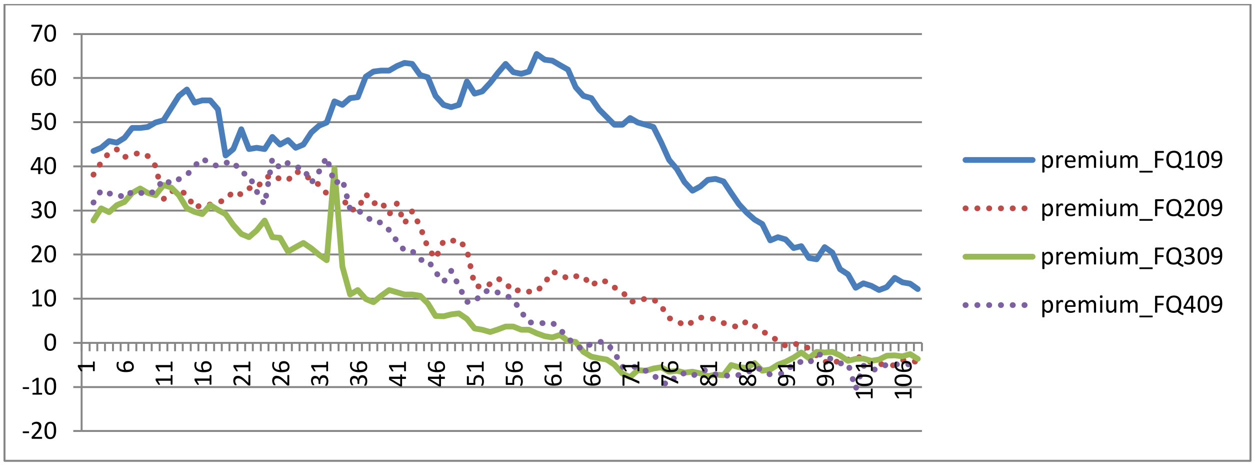


For 2009 we only have data on quarterly forward contracts for Powernext, unfortunately. As one can see in Graph 5.5, premiums are positive for all quarterly contracts, most of the time; the Q1-contract shows the biggest premium, followed by the Q2-, Q4- and Q3-contracts, respectively.

Graph 5.4 : Last 107 price observations per quarterly forward contract for the year 2008



Graph 5.5 : Last 107 price observations per quarterly forward contract for the year 2009



Summarizing, we can state that the before mentioned results are too ambiguous to support or contradict the findings of Cartea and Villaplana [2008], nor our own logical inferences based on their theory. The graphs above seem to contradict the fact that premiums for Q1- and Q3- delivery should be higher than those for Q2- and Q4-delivery, but graphical analysis alone is not enough. Unfortunately, due to time constraints, we cann ot include an empirical analysis on this matter; future research might be more enlightening.

5.2 Regression analysis

This section is divided into four parts. First, regressions (5) and (6) of Fama and French [1987] are performed on all available data, to get a global picture of all variables involved. Second and most importantly, the spot price change and risk premium regressions are conducted following event study methodology. In doing so, we try to isolate the effect of TLC market coupling on the different parameters. Third, regressions (5) and (6) are performed on the price data of quarterly base load electricity forward contracts. Fourth and finally, the forward risk premium is regressed on skewness and variance in order to test the first two hypotheses of Bessembinder and Lemon [2002]. All regressions are performed while using the natural logarithm of electricity prices.

5.2.1 Statistics on all available data

Table 2 reports the estimates of the parameters in the spot price change regression (5) and the risk premium regression (6) on the forward basis. For APX, Belpex and Powernext the results for the forward contracts with a maturity of one month (M1) and one year (Y1) are shown. The number of observations is after adjustments have been made.

Table 2 : Results of the spot price change (5) and risk premium (6) regressions for all availabe data

M1	**Max.**	**Obs.**	β_1	β_2	**t** (β_1)	**t** (β_2)	R_1^2	R_2^2
APX	94	1685	0.75	0.25	36.31***	12.21***	0.439	0.081
Belpex	88	1600	0.30	0.70	17.11***	40.63***	0.155	0.508
Powernext	77	1553	0.81	0.19	33.78***	8.04***	0.424	0.040
Y1	**Max.**	**Obs.**	β_1	β_2	**t** (β_1)	**t** (β_2)	R_1^2	R_2^2
APX	94	1568	1.15	-0.15	40.96***	-5.48***	0.517	0.019
Belpex	88	1427	0.68	0.32	41.08***	19.50***	0.542	0.211
Powernext	77	1387	1.13	-0.13	54.84***	-6.45***	0.685	0.029

To denote if a test statistic is statistically significant, ***, ** and * are used to indicate a 1%, 5% and 10% level of significance, respectively. R_1^2 and R_2^2 are the coefficients of determination for the change and premium regressions, respectively. Obs. is the number of observations in a regression, and Max. is the number of months in the sample period.

At first glance, a striking aspect of the results shown in Table 2 is that all coefficients, for both the M1 (delivery in the upcoming month) and Y1 (delivery in the upcoming year) contracts, are significantly different from zero at the 99-percent confidence level (t-statistics are all above the critical, absolute value of 2.576). This is where most of the similarity ends, though. For clarity reasons, we will follow the categorization of Fama and French [1987] into types *SF (strong forecast power), GF (good forecast power), SP and GP (expected premiums), F&P (forecast power and expected premiums)* and *W (weak)*. Remember that summing up β_1 and β_2 estimates must result in 1.0; all variation in the basis is always allocated to the expected premium, the expected change in the spot price, or a certain mix of the two.

Type SF – strong forecast power. Evidence for forecast power is strong for the APX and Powernext for both maturities; i.e. the forward basis contains reliable information about future spot price changes for both the M1- and Y1-forward contracts. For APX, the β_1 estimates of 0.75 and 1.15 have corresponding values of the t-statistic of 36.31 and 40.96 respectively; β_1 estimates for Powernext equal 0.81 and 1.13 with t-values of 33.78 and 54.84 respectively. These t-values are very high and convincing, as are the corresponding coefficients of determination (R_1^2) which range between 0.424 and 0.685. For example, by looking at the R_1^2 statistic for the APX one-month forward contract, we can conclude that the forward basis alone explains 43.9% of the one-month spot price change.

F&P - forecast power and expected premiums. The Belpex forward contracts show both evidence of forecast power and time-varying expected premiums. However, the M1-contract seems to show stronger evidence of expected premiums; values of β_2, t (β_2) and R_2^2 are all substantially higher than their corresponding β_1 estimates. For the Y1-contract, estimates show the opposite picture, hence its forward basis seems to contain stronger forecast power.

5.2.2 Event study on TLC market coupling

In order to isolate the effect of TLC market coupling on the forecasting power of forward prices and/or the information in these prices about the premium to be realized at *T*, we mainly follow event study methodology. As previously stated in the methodology section of this paper, the coupling of power markets is the *event*, taking place on November 21, 2006.

We run the same regressions again, but data is now divided into a period before the market coupling took place (*pre*) and a period after the market coupling (*post*). As can be seen in Table 3 on the next page, both periods consist of exactly the same amount of data points for each market separately; in between markets the length of periods is different, though. This is caused by the fact that we tried to make each *pre* period as long as possible, while each collected dataset starts at a different calendar date.

Table 3: Pre- and post-event results of regressions (5) and (6) for the one-month forward contracts

M1	Max.	Obs.	β_1	β_2	t (β_1)	t (β_2)	R_1^2	R_2^2
APX								
Pre		668	0.80	0.20	27.05***	6.68***	0.524	0.063
Post		668	0.69	0.31	18.59***	8.35***	0.342	0.095
Belpex								
Pre		505	0.89	0.11	25.11***	3.11***	0.556	0.019
Post		505	0.22	0.78	7.29***	25.43***	0.096	0.562
Powernext								
Pre		359	0.91	0.09	18.40***	1.74*	0.487	0.008
Post		359	0.58	0.42	10.15***	7.30***	0.224	0.130

To denote if a test statistic is statistically significant, ***, ** and * are used to indicate a 1%, 5% and 10% level of significance, respectively. R_1^2 and R_2^2 are the coefficients of determination for the change and premium regressions, respectively. Obs. is the number of observations in a regression, and Max. is the number of months in the sample period.

At first glance, one can immediately point out interesting changes after the TLC market coupling took place. For all markets, values of β_1 were between 0.80 and 0.91 at first, but decreased significantly afterwards. As a logic result of the adding-up constraint, values of β_2 were between 0.09 and 0.20 at first, but increased significantly after the market coupling. In other words, the one-month forward basis before coupling contained strong, reliable forecast power of future spot prices; it did not contain convincing evidence of time-varying expected risk premiums. Forward prices after coupling still contained reliable, but weaker, forecast power for both APX and Powernext; contracts changed from being of *Type SF (strong forecast power)* into *Type F&P (forecast power and expected premiums)*. By looking at their R_2^2 estimates though, we can see that evidence for forecast power is still more convincing than it is for time-varying expected risk premiums. For Belpex however, the M1-contract changed from being of *Type SF (strong forecast power)* into *SP (strong expected premiums)*. It also contains evidence of forecast power, but we discard this on the basis of the R_1^2 estimate, which basically tells us that only about 10% of the one-month spot price change is explained by the forward basis.

Table 4: Pre- and post-event results of regressions (5) and (6) for the one-year forward contracts

Y1	**Max.**	**Obs.**	β_1	β_2	**t** (β_1)	**t** (β_2)	R_1^2	R_2^2
APX								
Pre		668	1.01	-0.01	23.80***	-0.13	0.460	0.000
Post		668	1.48	-0.48	38.33***	-12.46***	0.688	0.189
Belpex								
Pre		505	0.87	0.13	24.66***	3.61***	0.547	0.025
Post		505	0.93	0.07	72.68***	5.36***	0.913	0.054
Powernext								
Pre		359	0.88	0.12	54.77***	7.47***	0.894	0.135
Post		359	1.47	-0.47	41.88***	-13.29***	0.831	0.331

To denote if a test statistic is statistically significant, ***, ** and * are used to indicate a 1%, 5% and 10% level of significance, respectively. R_1^2 and R_2^2 are the coefficients of determination for the change and premium regressions, respectively. Obs. is the number of observations in a regression, and Max. is the number of months in the sample period.

Table 4 on the page before shows the results before and after TLC market coupling for the one-year (Y1) forward contracts. They are just as interesting as the M1 results, be it in another way. Before market coupling took place, the one-year forward basis contained strong, reliable forecast power on all markets. Afterwards, forward prices are even better predictors of future spot price changes; β_1 estimates changed from being between 0.87 and 1.01 at first, to ranging from 0.93 to 1.48 afterwards. For APX and Belpex, the t-values of the β_1 – coefficients nearly doubled or tripled in value; the same statistic decreased a bit for Powernext, but still remained highly significant. The coefficients of determination (R_1^2) show the same picture, namely big increases for both APX and Belpex and a small decrease for Powernext. Values used to range from 0.460 to 0.894, where they now range from 0.688 to 0.913.

Summarizing, we can state that Belpex Y1-forward contracts were of *Type SF (strong forecast power)* before market coupling and remained to be *Type SF* afterwards, be it even stronger. For both APX and Powernext, Y1-forward contracts were of *Type SF* before coupling, and turned out to be of "*Type EF (excellent forecast power)"* afterwards.

5.2.3 Quarterly base load electricity forward contracts

The spot price change (5) and risk premium (6) regressions of Fama and French [1987] are also performed on collected price data of quarterly base load electricity forward contracts. These contracts imply the delivery of 1 MWh of electricity during each day of the first (Q1), second (Q2), third (Q3) or fourth (Q4) quarter of a a calendar year. We will investigate to what extent the forward basis of these quarterly contracts has forecast power of future spot price changes and/or evidence of time-varying expected risk premiums.

As one can see in Table 5 on the next page, β_1 estimates are all highly significant and almost all values are just below or above 1.00; as a result of the adding-up constraint, most β_2 estimates are close to 0.00, but with differences in significance. Hence, most quarterly forward prices have strong forecast power of future spot price changes, while having (almost) no evidence of time-varying risk premiums. Nonetheless, there are some quarterly forward contracts that also contain significant evidence of risk premiums; these contracts are distinguished in Table 5.

It might be interesting to investigate whether there are differences in the strength of forecast power before and after coupling, and between the different countries, years and quarters. Since all β_1 estimates are significantly different from zero at the 99-percent level of confidence and the R_1^2 values are also

Table 5 : Results of regressions (5) and (6) for all available quarterly forward contracts

	Market	Max.	Obs.	β_1	β_2	t (β_1)	t (β_2)	R_1^2	R_2^2
Q4-04	**APX**	7	107	0.98	0.02	55.46***	1.06	0.967	0.011
Q1-05	**APX**	8	107	0.98	0.02	77.28***	1.69*	0.983	0.026
Q2-05	**APX**	**7**	**107**	**0.93**	**0.07**	**96.08*** **	**7.33*** **	**0.989**	**0.338**
Q3-05	**APX**	**8**	**107**	**0.84**	**0.16**	**19.50*** **	**3.58*** **	**0.784**	**0.109**
Q4-05	**APX**	7	107	0.90	0.10	14.41***	1.56	0.664	0.023
	BEL	**8**	**107**	**0.78**	**0.22**	**15.79*** **	**4.49*** **	**0.704**	**0.161**
Q1-06	**APX**	7	107	1.06	-0.06	57.90***	-3.21***	0.970	0.089
	BEL	8	107	1.09	-0.09	32.37***	-2.80***	0.909	0.070
	POW	7	107	1.16	-0.16	38.60***	-5.29***	0.934	0.211
Q2-06	**APX**	**6**	**107**	**0.87**	**0.13**	**24.52*** **	**3.80*** **	**0.851**	**0.121**
	BEL	**7**	**107**	**0.88**	**0.12**	**21.46*** **	**3.01*** **	**0.814**	**0.079**
	POW	6	107	0.97	0.03	27.57***	0.76	0.879	0.006
Q3-06	**APX**	**7**	**107**	**0.88**	**0.12**	**38.04*** **	**4.99*** **	**0.932**	**0.192**
	BEL	7	107	1.01	-0.01	46.08***	-0.59	0.953	0.003
	POW	7	107	1.22	-0.22	43.37***	-7.69***	0.947	0.360
Q4-06	**APX**	8	107	1.00	0.00	52.46***	-0.05	0.963	0.000
	BEL	8	107	0.97	0.03	66.51***	2.03**	0.977	0.038
	POW	7	107	1.02	-0.02	66.97***	-1.62	0.977	0.024
Q1-07	**APX**	7	107	0.96	0.04	27.41***	1.24	0.877	0.014
	BEL	8	107	0.96	0.04	38.65***	1.50	0.934	0.021
	POW	7	107	0.97	0.03	51.00***	1.33	0.961	0.016
Q2-07	**APX**	7	107	1.27	-0.27	13.77***	-2.88***	0.643	0.073
	BEL	7	107	1.17	-0.17	15.17***	-2.15**	0.687	0.042
	POW	6	107	1.02	-0.02	12.66***	-0.26	0.604	0.001
Q3-07	**APX**	7	107	1.05	-0.05	32.44***	-1.61	0.909	0.024
	BEL	8	107	1.04	-0.04	28.44***	-1.01	0.885	0.010
	POW	6	107	0.96	0.04	17.63***	0.79	0.747	0.006
Q4-07	**APX**	7	107	0.99	0.01	34.12***	0.46	0.917	0.002
	BEL	7	107	0.97	0.03	46.32***	1.60	0.953	0.024
	POW	6	107	0.93	0.07	26.30***	1.87*	0.868	0.032
Q1-08	**APX**	6	107	1.11	-0.11	80.31***	-7.72***	0.984	0.362
	BEL	6	107	1.18	-0.18	86.34***	-12.91***	0.986	0.614
	POW	6	107	1.21	-0.21	69.74***	-11.96***	0.979	0.577
Q2-08	**APX**	7	107	1.07	-0.07	54.74***	-3.48***	0.966	0.103
	BEL	7	107	0.98	0.02	65.84***	1.14	0.976	0.012
	POW	6	107	0.97	0.03	54.71***	1.46	0.966	0.020
Q3-08	**APX**	**8**	**107**	**0.78**	**0.22**	**17.22*** **	**4.81*** **	**0.738**	**0.180**
	BEL	**9**	**107**	**0.85**	**0.15**	**59.47*** **	**10.57*** **	**0.971**	**0.515**
	POW	**6**	**107**	**0.72**	**0.28**	**10.81*** **	**4.13*** **	**0.527**	**0.140**
Q4-08	**APX**	**9**	**107**	**0.65**	**0.35**	**7.26*** **	**3.94*** **	**0.334**	**0.129**
	BEL	**10**	**107**	**0.78**	**0.22**	**50.02*** **	**13.97*** **	**0.960**	**0.650**
	POW	**6**	**107**	**0.90**	**0.10**	**18.25*** **	**2.00** **	**0.760**	**0.037**
Q1-09	**POW**	**7**	**107**	**0.63**	**0.37**	**10.90*** **	**6.27*** **	**0.531**	**0.273**
Q2-09	**POW**	**10**	**107**	**0.56**	**0.44**	**5.17*** **	**4.07*** **	**0.203**	**0.136**
Q3-09	**POW**	10	107	1.01	-0.01	8.13***	-0.07	0.386	0.000
Q4-09	**POW**	11	107	1.08	-0.08	10.18***	-0.77	0.497	0.006

To denote if a test statistic is statistically significant, ***, ** and * are used to indicate a 1%, 5% and 10% level of significance, respectively. R_1^2 and R_2^2 are the coefficients of determination for the change and premium regressions, respectively. Obs. is the number of observations in a regression, and Max. is the number of months in the sample period. Finally, the bold figures are those contracts which contain evidence of time-varying risk premiums as well as forecast power (i.e. *Type F&P*).

promising, Table 6 shows all β_1 estimates separately along with their t-statistics, in order to make comparing easier.

Table 6 : Results of the spot price change regression (5) for all available quarterly forward contracts

Q1	2004	2005	2006	2007	2008	2009
APX	x	0.98 (77.28)	1.06 (57.90)	0.96 (27.41)	1.11 (80.31)	x
Belpex	x	x	1.09 (32.37)	0.96 (38.65)	1.18 (86.34)	x
Powernext	x	x	1.16 (38.60)	0.97 (51.00)	1.21 (69.74)	**0.63 (10.90)**
Q2						
APX	x	**0.93 (96.08)**	**0.87 (24.52)**	1.27 (13.77)	1.07 (54.74)	x
Belpex	x	x	**0.88 (21.46)**	1.17 (15.17)	0.98 (65.84)	x
Powernext	x	x	0.97 (27.57)	1.02 (12.66)	0.97 (54.71)	**0.56 (5.17)**
Q3						
APX	x	**0.84 (19.50)**	**0.88 (38.04)**	1.05 (32.44)	**0.78 (17.22)**	x
Belpex	x	x	1.01 (46.08)	1.04 (28.44)	**0.85 (59.47)**	x
Powernext	x	x	1.22 (43.37)	0.96 (17.63)	**0.72 (10.81)**	1.01 (8.13)
Q4						
APX	0.98	0.90 (14.41)	1.00 (52.46)	0.99 (34.12)	**0.65 (7.26)**	x
Belpex	x	**0.78 (15.79)**	0.97 (66.51)	0.97 (46.32)	**0.78 (50.02)**	x
Powernext	x	x	1.02 (66.97)	0.93 (26.30)	**0.90 (18.25)**	1.08 (10.18)

The bold figures are those contracts which contain evidence of time-varying risk premiums as well as forecast power (i.e. *Type F&P*). The numbers in between brackets are the t-statistics. Contracts for which we did not have enough observations, are not analysed and denoted with an ‘x’.

The bold figures are those contracts which are also distinguished in Table 5. The first thing that strikes the eye is that for all three power markets, quarterly forward contracts concercing delivery of electricity during the third and fourth quarter of 2008 start showing evidence of time-varying risk premiums. This evolution continues for Powernext in the first half a year of 2009, for which we unfortunately do not have observations for APX and Belpex. Contracts implying the delivery of electricity in the third quarter of 2006 up to and including the second quarter of 2008 do not show evidence of risk premiums at all, with the exception of the Q3-06 contract for APX. For this market, forecast power for future spot price changes started declining between the Q1-05 up to and including the Q3-06 contract, excluding the Q1-06 contract, which showed no evidence of risk premiums at all. For Belpex, the picture is less clear; forecast power increased between the Q4-05 and Q1-06 contracts, decreased between Q1-06 and Q2-06 and increased close to 1.00 afterwards. Quarterly forward contracts on Powernext showed nothing but forecast power, until the third quarter of 2008.

When comparing prices of quarterly forward contracts over the years, the Q1- and Q2-contracts for all three markets do not show significant changes between 2005 and 2007. Forecast power of first-quarter delivery contracts increases significantly between 2007 and 2008 for all markets, where it decreases significantly for second-quarter delivery. Powernext shows a significant decrease in forecast power between 2008 and 2009 for both contracts, where it would be interesting to have data for APX and Belpex as well. The third-quarter and fourth-quarter delivery contracts for all markets decrease in forecast power between 2007 and 2008. Thereafter, Powernext shows a significant increase in forecast power for these contracts between 2008 and 2009.

The interesting thing about the before mentioned results is that one would expect forecast power of future spot price changes to increase for all quarters of the years after the TLC market coupling in the last quarter of 2006, but this does not seem to be the case. If we assume that the effect of market coupling is included from the Q3-07 contracts onwards (price observations for older contracts include the calendar day of coupling itself, i.e. November 21, 2006), we can actually conclude the contrary. Between 2007 and 2008 evidence of time-varying risk premiums increases, especially for the Q3- and Q4-delivery contracts. The Q2-contracts are still of *Type SF (strong forecast power)*, even though there is a significant decrease in forecast power as well. The Q1-contracts show a significant increase in forecast power between these years. Powernext results over 2009 make the story even more ambigious, since forecast power of Q1- and Q2-contracts drastically decreases while it increases significantly for the Q3- and Q4-contracts.

Concluding, we can state that between the third quarter of 2006 and the third quarter of 2008, forward prices were of *Type SF (strong forecast power)*; the Q3-06 APX contract is the only exception with some evidence of risk premiums. Afterwards, evidence of time-varying risk premiums seems to become stronger for all three power exchanges. This is a surprising result, since one would expect TLC market coupling to make forecasting of future spot prices easier, hence decreasing risk premiums. Future research on more data of quarterly contracts might be helpful to get a clearer picture.

5.2.4 Skewness and variance in relation to the forward risk premium

According to Bessembinder and Lemon [2002], the forward premium is positively related to the skewness and negatively related to the variance of electricity spot prices. In section 5.1.1 of this research paper, we already tried to make some judgements on these statements by graphical analysis. Our conclusion was that skewness indeed seems to have an increasing effect on the risk premium, but variance seems to have the same effect as well. Since the latter does not correspond to the findings of Bessembinder and Lemon [2002], an empirical analysis is performed to double-check our conclusion. Remember the following two regressions from the methodology section:

$$F(t, T) - S(T) = \alpha_1 + \upsilon\,(\text{var}) + \varepsilon$$

$$F(t, T) - S(T) = \alpha_1 + \gamma\,(\text{skew}) + \varepsilon$$

According to Bessembinder and Lemon [2002], γ should be positive and υ should be negative. Table 7 below shows the results of these regressions for both the one-month and one-year forward contracts.

Table 7 : Regression results of the M1- and Y1-premiums on skewness and variance of electricity spot prices

M1	**Max.**	**Obs.**	υ	γ	**t** (υ)	**t** (γ)	R_υ^2	R_γ^2
APX	94	1685	0.000	-0.004	5.47***	-0.74	0.017	0.000
Belpex	88	1600	-0.000	0.016	-2.48**	1.37	0.004	0.001
Powernext	77	1553	0.000	0.009	1.62	1.40	0.002	0.001
Y1	**Max.**	**Obs.**	υ	γ	**t** (υ)	**t** (γ)	R_υ^2	R_γ^2
APX	94	1568	0.000	-0.048	1.52	-5.91***	0.001	0.022
Belpex	88	1427	0.000	0.062	6.96***	6.93***	0.033	0.033
Powernext	77	1387	-0.000	-0.031	-0.56	-4.20***	0.000	0.013

To denote if a test statistic is statistically significant, ***, ** and * are used to indicate a 1%, 5% and 10% level of significance, respectively. R_υ^2 and R_γ^2 are the coefficients of determination for the variance and skewness regressions, respectively. Obs. is the number of observations in a regression, and Max. is the number of months in the sample period.

One can immediately see that all R^2 values are close to zero; the Belpex Y1-contracts have the highest R^2 values with 0.033, which means that both variance and skewness alone explain 3.3% of the change in the forward risk premium. While keeping in mind that these values are relatively small, we merely want to see if the relation between both parameters and the premium is positive or negative.

Starting off with the APX, the relation between the M1-premium and variance is neither positive nor negative on the 99-percent level of confidence. For the same contract we find a very small negative relation between the premium and skewness, but by looking at the values of the t-statistic and R^2, this effect is negligible. For the Y1-contracts, variance again neither seem to have a positive or negative relation with respect to the premium, but evidence is weaker by looking at the relevant statistics. Surprisingly, skewness seems to show a negative relation with the premium; even though this effect is rather small, evidence is highly significant.

For Belpex, the M1-contract shows a very small and negative relation between the premium and variance, which is significant on the 95-percent confidence level. Skewness seems to show a small positive relation, but it is not significant. The Y1-results are both highly significant; variance does not seem to influence the one-year risk premium and skewness has an increasing effect on this premium.

Finally, when looking at the results for Powernext, we can state that there is no evidence for a relationship between variance and/or skewness and the M1-premium. All results are close to zero and not significant. Moreover, we do not find proof of any relation between variance and the Y1-premium. We do find a highly significant and negative relation between skewness and the Y1-premium though.

Summarizing, we can state that according to our findings, variance of wholesale prices on all power exchanges does not seem to influence the risk premium at all, nor for the M1- or Y1-contracts. Skewness only has a significant and positive effect on the Y1-premium for Belpex. The other positive relations we find are for the M1-contracts on Belpex and Powernext, but these results are not significant. Most surprising are the Y1-results for APX and Powernext; even though the effect is small, we find a highly significant and negative relationship between skewness and both forward risk premiums. This would mean that the premium decreases after an increase in skewness, which contradicts the findings of Bessembinder and Lemon [2002] and our own results after graphical analysis.

6 Conclusion

The main goal of this research paper is to shed more light on the effect of TLC market coupling on the forecast power and evidence of time-varying risk premiums of the forward basis. Besides significant evidence in support of the expectations theory, our analysis also provides interesting results for the impact of market coupling, especially for the one-month forward electricity contracts. Before coupling, these contracts contained strong forecast power and almost no evidence of risk premiums for APX, Belpex and Powernext. Afterwards, forward prices still contain reliable, but weaker, forecast power for both APX and Powernext; evidence of risk premiums is also found. This evidence is strongest for Belpex, where M1-contracts change from *Type SF (strong forecast power)* into *Type SP (strong expected premiums)*. Even though forecast power of all one-year forward contracts was already strong, it increases significantly as a result of market coupling, especially for APX and Powernext.

Quarterly forward contracts concerning the delivery of electricity between the third quarter of 2006 and the second quarter of 2008 are of *Type SF (strong forecast power)* for all power exchanges; the only exception to the rule is the APX-Q306 contract, which also contains evidence of time-varying expected risk premiums. For all three power exchanges, evidence of time-varying risk premiums becomes more profound for the quarterly forward contracts concerning delivery of electricity in the last two quarters of 2008. In 2009, this evolution continues for the Q1- and Q2-delivery contracts on Powernext, but its Q3- and Q4-forwards contain no evidence of risk premiums at all. Unfortunately, we do not have quarterly forward data for APX and Belpex over 2009; it would have been interesting to include those results as well.

Furthermore, our graphical analysis seems to support our expectations of a stabilizing effect of market coupling on both electricity spot and forward prices. It does not support all findings of Bessembinder and Lemon [2002]: for APX, Belpex and Powernext, the one-month risk premiums indeed seem to increase in the anticipated skewness of wholesale prices, but they do not decrease in the anticipated variance. After regression analysis on this matter, we can state that according to our findings, variance of wholesale prices on all power exchanges does not seem to influence the risk premium at all, nor for the M1- or Y1-contracts. Skewness only has a significant and positive effect on the Y1-premium for Belpex. The other positive relations we find are for the M1-contracts on Belpex and Powernext, but these results are not significant. Most surprising are the Y1-results for APX and Powernext; even though the effect is small, we find a highly significant and negative relationship between skewness and both forward risk premiums. This would mean that the premium decreases after an increase in skewness, which contradicts both the findings of Bessembinder and Lemon [2002] and the results of our own graphical analysis.

Finally, where risk premiums are indeed higher for Q1- and Q3-delivery (winter and summer, respectively) in 2005 and 2007, the picture is less uniform for the years 2006, 2008 and 2009. Therefore it is hard to make any statements concerning seasonal effects on the risk premium in this research paper.

Future research on the relation between skewness, variance and the forward risk premium for the TLC market might be of interest; the same holds for the seasonal impact on premiums. Moreover, we applaud extended research on the increasing evidence of time-varying risk premiums in one-month and quarterly forward electricity prices after TLC market coupling.

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