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Working Paper No. 2009-7

**Risk Premia in the German Electricity
Futures Market**

MATTHÄUS PIETZ

WORKING PAPER SERIES



**Center for Entrepreneurial and
Financial Studies**



Risk Premia in the German Electricity Futures Market

Matthäus Pietz*

The mechanism behind price formation in electricity futures markets is still under discussion. Theory suggests that hedging pressure caused by deviating risk preferences is the most promising approach. This paper contributes to the discussion through an empirical investigation of electricity futures for delivery in Germany traded at the European Energy Exchange (EEX). We analyse the futures from an ex post perspective and find evidence for significant positive risk premia at the short-end. Furthermore, we detect a term structure of risk premia and the existence of seasonality in the risk premia. When testing for factors influencing the risk premia the results suggest that risk premia are directly related to factors linked to risk considerations.

Keywords: Electricity Market, Forward Market, Futures Market, Risk Premia, Risk Premium

JEL classification: G13, L94, Q40

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1. Introduction

Shortly after the worldwide deregulation of electricity markets and the establishment of electricity exchanges the academic literature recognized that the pricing of electricity futures is not feasible with the well-established models. In contrast to financial and other commodity markets, where mostly the cost-of-carry approach as a non-arbitrage condition can be applied, electricity reveals a basic characteristic, the non-storability, which makes the cost-of-carry approach not applicable. Thus, the question about the mechanism behind price formation in electricity futures markets is of high importance, both for academics and practitioners.

From an equilibrium point-of-view the risk premia approach seems to be most promising. In general this approach identifies two possible determinants of risk premia: systematic risk and hedging pressure (Bessembinder 1992). The existence of systematic risk, defined as the covariance between the futures returns and the returns of the market portfolio, in commodity futures is under controversial discussion in the empirical literature (Dusak 1973, Bodie and Rosansky 1980, Jagannathan 1985). The second determinant, hedging pressure, is based on the normal backwardation theory formulated by Keynes (1930). Later this theory was extended to the general hedging pressure theory. This theory indicates that futures prices can be seen as the sum of the expected spot price at maturity and a risk premium. The risk premium is paid by risk-averse market participants as a compensation for the elimination of price risk. Empirical results concerning hedging pressure in commodity markets are mixed (Fama and French 1987, de Roon et al. 2000).

Regarding price formation in electricity forward markets literature suggests that the hedging pressure theory seems to be appropriate. The risk premia can be both positive as well as negative. Empirical results indicate that risk premia in electricity markets are mostly positive, at least for short- and mid-term futures.¹ This is contrary to other markets as positive risk premia translate to a negative price of risk (Kolos and Ronn 2008), meaning that a long position in such a market is on average linked to negative returns.

¹ The terminology used in this paper is as follows: Futures with a maturity between one and three months are considered as short-term, with a maturity between four and twelve months as mid-term and with a maturity over twelve months as long-term futures.

A plausible economic interpretation of positive risk premia is that holders of long positions in futures are compensating holders of short positions for the bearing of price risk. Under the assumption that prices are set by industry participants – and not by outside speculators – this implies that electricity consumers rather than producers are more interested in hedging. Since price risk is an essential risk in the short run, mainly due to frequently emerging price peaks, this explanation seems to be appropriate.

Assuming that electricity consumers are mainly interested in hedging their short-term price exposure, one can argue that the sign of the risk premia can change according to the time horizon considered. Electricity consumers use short-term futures for hedging purposes while producers use mainly long-term futures. The economic rationale behind the producer behaviour may be the long-term character of investments in the energy industry. This results in demand for long-term futures to hedge cash flows far in the future to gain at least some planning reliability for investment decisions. In consequence, the behaviour of both consumers and producers may result in market segmentation which translates into positive risk premia in short-term and negative risk premia in long-term futures. Benth et al. (2008) develop a framework to model this effect using risk preferences and market power.

This paper aims to test the adequacy of the risk premia approach for the German electricity futures market which is located at the European Energy Exchange (EEX). Our dataset covers the period between July 2002 and December 2008. We analyse the risk premia from an ex post perspective and show that there is evidence for significant positive risk premia in short-term futures. After a rise at the short-end the risk premia seem to decrease with increasing time-to-delivery. However, our dataset is too small to test for the above discussed market segmentation. Furthermore, we find evidence for the existence of seasonality in the risk premia. Risk premia in futures with delivery in winter seem to be positive, whereas risk premia in futures with delivery in summer are zero or even negative. In addition we link the risk premia to risk considerations. Our contribution to the existing literature is at least three-fold. First, we find evidence for positive risk premia in the German futures market. Second, we find a term structure of risk premia. And third, we carefully discuss the problematic interpretation of risk premia considering the underlying assumption of random forecast errors.

This paper is organised as follows: The second section contains a description of the EEX and the trading in the futures market. The third section gives an overview on the theory

behind risk premia in electricity markets and a literature review on the relevant research on this topic. In the fourth section we describe our dataset, report descriptive statistics, estimate the risk premia and test for drivers of the risk premia. Section five summarizes our results.

2. The European Energy Exchange

In the first section of this chapter we give an overview on the European Energy Exchange (EEX). The second section explains the trading mechanism on the futures market of the EEX and the traded contracts.

2.1 Market Fundamentals

For decades electricity trading all over the world was characterized by a monopolistic structure on the supply side and bilateral long-term contracts between end-users and utilities or distributors. Due to the lack of a public electricity market the pricing mechanism was intransparent and competition was lacking. The start of the deregulation of electricity markets in the United Kingdom and in Norway at the beginning of the 90s marked the start of a transformation process. This liberalisation of energy markets was based on the insight that markets are a better allocation mechanism than the existing system. The purpose of the reform was hence the introduction of free markets and a transformation of the cost-based regulation into a market-oriented price formation. This was supposed to end monopoly control and to bring prices down.

The introduction of competition also drove the need for marketplaces and was the cornerstone for the establishment of energy exchanges. In Germany, the marketplace for electricity is now the European Energy Exchange (EEX) in Leipzig. The EEX is an electronic exchange which was founded in 2002 as a result of a merger between the Leipzig Power Exchange (LPE) and the former European Energy Exchange, previously based in Frankfurt am Main.

Due to Germany's status as Europe's largest economy and also as Europe's largest electricity market, both in production and consumption, the EEX is the largest energy exchange in continental Europe. Over 220 participants from over 20 countries participate in trading at the moment. Other important energy exchanges in Europe are the Nord Pool for the Scandinavian area, the Powernext for France, the APX for England and the Netherlands, and

the OMEL for Spain. The development of electricity exchanges is still an ongoing process with an expected consolidation in the next years.

Traded commodities at the EEX are gas, coal, electricity, and emission allowances. In addition to the exchange trading the clearing of forward contracts is also possible. The electricity market consists of a spot and a derivatives market. The spot market is comprised of two submarkets, an intraday and a day-ahead market, a market structure which can be found on most energy exchanges. On the day-ahead market hour contracts with delivery on the next day are traded. The pricing mechanism consists of a uniform auction. The intraday market is operated as a continuous market. Electricity is traded on this market up to 75 minutes before delivery.

2.2 Trading On The Futures Market

Together with the options market the futures market forms the derivatives market of the EEX. On the options markets European-type options on the Phelix Base (see below) are traded. Traded options are available on the next five month futures, the next six quarter futures and the next three year futures. An option series is available for every future. The liquidity of this market is extremely low.

Phelix (Physical Electricity Index) is the index of the spot market (i.e. the day-ahead market) of the EEX. The Phelix represents the daily average price and is calculated as a simple average of the 24 hourly prices (base) or between 8 am and 8 pm (peak). The Phelix Base and Phelix Peak are calculated for all 365 days of the year. A monthly Phelix Base (Peak) as the arithmetic mean of the daily prices (daily prices between Monday and Friday) is also calculated.

Three kinds of futures are traded on the futures market. These futures are characterised by their delivery period, e.g. one month, one quarter or one year. The settlement of futures can take place either in cash or physical, according to the contract specifications.² The main part of the liquidity in the futures market is observed in the cash-settled futures. Thus we only take these futures into consideration in the following. There is a base and a peak version for every future. A base contract ensures delivery around the clock and a peak contract delivery

² Physical settlement occurs in the German Base Load Future, the German Peak Load Future, the French Base Load Future and the French Peak Load Future. Cash settled futures are the Phelix Base Future and the Phelix Peak Future.

between 8 am and 8 pm. Thus a month future ensures for example the delivery of electricity with a constant around the clock delivery rate of 1 MW on any delivery day of a calendar month (base) or on all delivery days from Monday until Friday from 8 am to 8 pm (peak).³ The Phelix Base and Phelix Peak Index are the underlying for the cash-settled base and peak future, respectively.

Currently traded delivery periods are the actual month, the next nine months, the next eleven quarters and the next six years. A special feature of the futures market is the cascading of the quarter and year futures. In the case of quarter futures the original future is replaced through three month futures before the delivery period. The year future is replaced through three quarter and three month futures.

3. Theoretical Background

In the first section of this chapter we introduce the risk premia approach. In the second section we give an overview on the existing empirical literature.

3.1 Risk Premia

Hedging pressure arises from equilibrium considerations and dates back to Keynes (1930) and Hicks (1939). Later it was generalized to the general hedging pressure theory⁴ (Cootner 1960) and, more recently, systematic risk and hedging pressure have been merged to joint models (Stoll 1979, Hirshleifer 1988, Hirschleifer 1989). Fama and French (1987) conducted a broad empirical investigation of commodity futures.⁵

A definition of the risk premium requires the specification of a temporal perspective, resulting in two different, necessarily to distinguish definitions. The first is known as the ex ante or expected risk premium, the second as the ex post or realised risk premium. To define

³ Delivery of electricity traded at the EEX takes place in one of the following six zones: RWE Transportnetz Strom, EON Netz, Vattenfall Europe Transmission, ENBW Transportnetz, Austrian Power Grid and swissgrid.

⁴ Keynes assumed that producers always pay the risk premium to get rid of their price risk. Under the assumption that the expected spot price equals the current price that results in a down sloping term structure, a situation known as backwardation. Hence Keynes' theory is termed normal backwardation. The generalisation was derived from the insight that consumers can pay the risk premium as well.

⁵ Fama and French (1987) analyse the price formation mechanism for commodity futures for 21 commodities. Their main task is the empirical validation of the theory of storage and the hedging pressure theory. While finding support for the first theory, the results for the hedging pressure theory are mixed.

the risk premium, we will use the following notation in this paper: π stands for the risk premium, $S(t)$ the spot price at time t and $F(t,T)$, the futures price at time t , for a future with delivery in T . E_t equals the expectation operator at time t . Only information that is available up to this time is included in the expectations.

The ex ante risk premium at time t in a future with delivery in T is defined as

$$\pi(t,T) = F(t,T) - E_t[S(T)]. \quad (1)$$

The unobservable expected spot price is critical for the use of the ex ante risk premium is. Empirical research on the ex ante risk premium hence always requires a specification of a spot price model. The choice of an appropriate spot price model is essential for the obtained risk premium and very sensitive to the specific assumptions.⁶ Consistent and robust results are therefore difficult to obtain.

The ex post premium is defined as

$$\pi(T) = F(t,T) - S(T). \quad (2)$$

The notation of the risk premium, $\pi(T)$, signals that the observation takes place at maturity of the future in T . The advantage of this definition is the availability of all relevant data.

Definition (1) and (2) can be linked through equalizing and result in

$$\pi(t,T) - S(T) = F(t,T) - E_t[S(T)] - S(T). \quad (3)$$

Under the assumption that market participants form their forecasts based on rational expectations equation (3) can be written as

$$F(t,T) - S(T) = \pi(t,T) + \varepsilon_t. \quad (4)$$

Under equation (4) the ex post risk premium equals the ex ante risk premium plus a noise term. Because the market participants form their expectations rationally it is assumed that the resulting average forecasting error is zero. That is a strong assumption, especially for a young market with a low number of market participants trading a commodity with special

⁶ See Karakatsani and Bunn (2005) for a discussion of problems regarding the use of spot price models.

characteristics. We will discuss this critical assumption in the empirical part further but remark already here that an interpretation of ex post risk premia is always problematic due to this assumption.

For empirical purposes we will calculate the ex post risk premium as

$$\pi(T) = \frac{1}{T} \sum_{t=1}^T (F(t, T) - S(T)). \quad (5)$$

The spot price $S(T)$ is calculated as the average of the hourly prices during the delivery period

$$S(T) = \frac{1}{n} \sum_{i=1}^n S_i(t) \quad (6)$$

with n being the number of hours during the delivery period.

In addition we calculate a relative risk premium defined as

$$\pi_{rel}(T) = \frac{1}{T} \sum_{t=1}^T \left(\frac{F(t, T) - S(T)}{F(t, T)} \right). \quad (7)$$

The relative risk premium can be interpreted as the percentage of the futures price which is paid due to hedging purposes.

The adequacy of the risk premia approach for electricity futures prices suggests that the futures prices can not be seen as unbiased estimators of the expected future spot price. Rather they reflect the demand and supply for hedging instruments (Karakatsani and Bunn 2005).

3.2 Related Literature

The work of Bessembinder and Lemmon (2002) is probably the most influential theoretical paper on electricity futures, at least according to the number of citations. The authors develop an equilibrium model for electricity forward pricing with closed form solutions. Implications of their model are negative risk premia in the case of expected low demand and demand risk. An increase of these two variables leads to an increase of risk premia which can even result in positive risk premia. The model hence links risk premia to risk considerations.

Obtained empirical results on risk premia can be divided into two groups. The first group concentrates on short-term risk premia, mainly defined as the price difference between the hour contracts in the day-ahead and the intraday markets. Contributions to this research are made among others by Longstaff and Wang (2004), Diko et al. (2006), Hadsell and Shawky (2007) and Ronn and Wimschulte (2008). The results of this research are mostly the detection of risk premia which vary throughout the day and are highly volatile. In general the risk premia are positive during hours of high demand. The other group examines long-term risk premia, focusing mostly on the analysis of week and month futures. Botterud et al. (2002), Shawky et al. (2003), Bierbrauer et al. (2007), Wilkens and Wimschulte (2007), Furio and Meneu (2009), Lucia and Torro (2008), Torro (2008), Kolos and Ronn (2008) and Marckhoff and Wimschulte (2009) contribute to this research. We focus our literature review on these empirical studies.

Botterud et al. (2002) report first results concerning the Nord Pool. They find positive risk premia in futures with a time-to-delivery up to one year covering the sample period 1995 to 2001. Shawky et al. (2003) investigate futures with delivery in the region of California-Oregon traded on the NYMEX and find positive risk premia. Their dataset includes the years 1998 and 1999. Data from the Nord Pool are again analyzed by Lucia and Torro (2008). Their dataset covers the period 1998 to 2007 and consists of the four closest-to-delivery week futures. The authors find significant positive risk premia. Their results are indirectly confirmed in a further paper by Torro (2008). Furio and Meneu (2009) investigate the Spanish electricity market for long-term risk premia, using both the ex ante and the ex post approach. Covering a sample period between 2003 and 2006 containing data of the first-to-deliver month future they find that overall the ex post risk premia are negative but not statistically significant. However, the ex ante risk premia are positive. Marckhoff and Wimschulte (2009) analyse Contracts for Difference (CFD) at the Nord Pool. CFD allow to hedge against price differences among different delivery areas and were first traded at the Nord Pool at the end of 2000. The authors find significant short-term positive risk premia and negative long-term risk premia.

First results on risk premia on the EEX are reported in Wilkens and Wimschulte (2007). The authors analyse the pricing of futures on the EEX between 2002 and 2004 in their paper. They restrict their study to month futures with a maturity of up to six months. After estimating ex ante risk premia they compare their results with ex post risk premia. The authors find positive risk premia, both from an ex ante as well as an ex post perspective. The

risk premia are highly volatile and change regularly in sign. Bierbrauer et al. (2007) give an overview on the established models for forecasting electricity spot prices. They test these models on data from the EEX and identify three models which best fit the data. Using them for the forecast of ex ante risk premia they find positive risk premia for the short-term and mid-term and negative risk premia for the long-term contracts. Kolos and Ronn (2008) aim to estimate the market price of risk. To do this, they estimate the risk premia. For the EEX, with a dataset covering the period 2002 to 2006, they find positive risk premia.

4. Empirical Results

In the first section of this chapter we describe our dataset and report descriptive statistics. The second section contains results on the risk premia. Finally, in the third section, drivers of the risk premia are identified and discussed.

4.1 Data and Descriptive Statistics

Our dataset consists of data from the day-ahead and futures market of the EEX and covers the period between July 1, 2002 and December 30, 2008. The data was obtained directly from the EEX.

The data for the day-ahead market consists of hourly prices and is available for 365 days a year. The daily and monthly Phelix Base and Phelix Peak Index are computed by the EEX and are included in our dataset. Both the day-ahead as well as the futures prices are expressed in Euro/MWh. To simplify the terminology we refer to the day-ahead market in the following as the spot market and report prices only in Euro.

The futures market data consists of daily prices. Due to liquidity considerations we only take the Phelix Base and Phelix Peak Future into account. Futures tradable at the beginning of our sample period were: a month future with delivery during the trading month, month futures with a time-to-delivery of up to six months, quarter futures for the next seven quarters and year futures for the next three years. Over the past years new futures were introduced by the EEX to extend the term structure. To ensure comparability we restrict our analysis to futures with time-to-deliveries consistent to the ones available at the beginning of our sample period. In addition to the price data, open interest and traded volume are available. Futures market data are only available for business days.

The following analysis excludes the month future with the shortest time-to-delivery due to its special characteristics. The settlement of a cash-settled future consists in the payment of the difference between the price at opening the position and the realised average spot price during the delivery period.⁷ Trading in the delivery period hence effectively leads to a conversion in a future with a shorter delivery period. This leads to a lower volatility and a convergence of the futures price to the average spot price.

Before reporting descriptive statistics the liquidity of the futures market is to be discussed. Liquidity is important when analysing data on electricity markets since electricity exchanges are wholesale markets and the number of market participants is limited. Two measures of liquidity can be used for futures markets: the open interest and the traded volume. First, we examine the development of the open interest during our sample period.

In the fourth quarter of 2002 the daily open interest in all futures contracts averaged to approximately 28 TWh. At the end of our sample period, the last quarter of 2008, an average open interest of 356 TWh was observed. This represents an astonishing increase of open interest of almost 1300 percent in six years and speaks for a liquid and well-developing market. This smooth increase in the open interest took place along with an increasing number of market participants, available tradable contracts and number of traded contracts.

A typical pattern is observed regarding the number of traded contracts. Trading mainly takes place in futures with a short time-to-delivery. The average daily number of traded contracts in the month futures, both base and peak, over our whole sample period is depicted in figure 1.

- Include figure 1 about here -

As shown, the maximum in traded contracts is reached in the days just before the start of the delivery period and decreases thereafter.⁸ A similar pattern is also observed by Shawky et al. (2003) for futures traded at the New York Mercantile Exchange with delivery at the California-Oregon Border. The decrease in traded contracts results in thin trading and an

⁷ We ignore the daily mark-to-market mechanism.

⁸ Almost no trading is observed during the delivery month (= last trading month).

increasing number of days without trading in mid-term and long-term futures.⁹ We therefore decide to restrict the following analysis to the month futures.¹⁰

The terminology employed can be clarified through an example. The first month future contract in our sample for which data over its whole trading period is available, is the future with delivery in February 2003. This future was traded between 02/07/31 and 03/02/27. In our analysis we handle the price data of this future as follows: The data point 02/07/31 is excluded. During trading in August this future is termed as a six month future, in September as a five month future and so on. Finally, in January, we term this future as a one month future. February data is excluded due to the problems discussed above regarding futures being traded in their delivery period.

The final dataset comprises 72 month futures observed over their whole trading period. They are characterised by their delivery month, e.g. February 2003. Considering the definition of the ex post risk premium and the problem of separating forecast errors and risk premia the low number of contracts is identified as the probable reason for a lack of comparable empirical studies on the German electricity futures markets.

Using the terminology introduced above we report in table 1 and 2 several descriptive statistics on the month futures, both for the base and peak version.

- Include table 1 about here -

The upper part of the table contains the descriptive statistics on the price data with monthly frequency. The lower part of the table contains the descriptive statistics on the return data. The returns are calculated as log returns. The corresponding values for data with daily

⁹ On days without trading in a particular contract the settlement price is established by using the so-called chief trader procedure. Every market participant is asked by the EEX for a price indication for this contract. The settlement price is then calculated by the EEX as an average under considerations of special constraints (see EEX 2008).

¹⁰ Through the cascading of the quarter and year futures an arbitrage relation between futures with different delivery periods at the short-end is established. For the price of the first quarter future, P_Q , for example the following relation applies

$$P_Q = \frac{n_1}{n} P_1 + \frac{n_2}{n} P_2 + \frac{n_3}{n} P_3$$

P_1 is hereby the price of the month futures with delivery in the first month of the delivery quarter of the quarter future and n_1 the number of delivery days in this month. The other values stand for the second and third month future. n is calculated as the sum of n_1 , n_2 and n_3 .

frequency are reported in brackets. The monthly data is calculated as the arithmetic average of all prices within one month.

- Include table 2 about here -

A smoothing is observed when comparing the daily and monthly prices. This was to be expected due to the lower sensitivity of monthly prices to price peaks. The average price increases between the first and third month future and remains constant thereafter. The prices for peak futures are on average 20 Euro or 45 percent higher than the base future prices. We observe a decreasing volatility with increasing time-to-delivery. Without further examination we conclude that this could be interpreted as the Samuelson Effect.¹¹

The observed high maximum values in futures prices are unexpected, especially when compared to the realised monthly prices on the spot market shown in figure 2.

- Include figure 2 about here -

It is apparent that the maximum future prices are higher than the highest realised prices on the spot market. In addition the positive skewness suggests that several observations were taken in this price region. There also seems to be a tendency for a comovement of spot and futures prices which results in a high correlation between the time series. For a further analysis of this behaviour we run a regression of the futures prices on the spot prices. When doing so, we take into consideration that a regression of two time series is only meaningful when both time series are stationary or cointegrated. Otherwise misleading results could be obtained due to spurious regression. Testing for unit roots in the time series using the Dickey-Fuller-Test yields the result that the null hypothesis (existence of a unit root) can not be rejected. Tests for cointegration deliver mixed results. We hence drive a regression with first differences and find a relationship between the spot and futures prices.¹²

The above results are also found in a recent work by Redl et al. (2009) who analyse the price formation in the futures markets of the EEX and Nord Pool. The authors find that

¹¹We also computed the volatility for the quarter and year futures and found a further decreasing volatility with increasing time-to-delivery. The Samuelson Effect (Samuelson 1965) indicates that the volatility of futures prices decrease as time-to-delivery increases. This is explained by a lower sensitivity of long-term futures to information inflow due to a longer remaining adjusting period.

¹² However, the results are mixed and not easy to interpret. Due to space considerations and the below discussed work of Redl et al. (2009) we forgo to report our results here.

fundamental expectations or risk considerations can not fully explain the difference between futures and spot prices. They conclude that an effect which they term “adaptive price formation” is apparently existent in both markets. This is interpreted as evidence for the existence of systematic forecast errors. These results question the assumption of rational expectations underlying our analysis. There is definite need for further research but considering the small size of our dataset we have to remark that the results listed below have to be interpreted carefully. The estimated risk premia may partially be the result of forecast errors. Other effects also have also to be considered when price differences between futures and realised spot prices are being interpreted (Borenstein et al. 2008).

4.2 Are There Risk Premia?

Using the monthly spot prices shown in figure 2 we estimate the risk premia contained in the month futures. The estimation follows equation (5) for the absolute risk premium and equation (7) for the relative risk premium. The futures prices are aggregated to monthly prices to overcome autocorrelation problems. The aggregation of the data results in a shortening of the time series for every future from approximately 150 observations to six monthly prices. Every monthly price is used for the computation of the risk premium with corresponding time-to-delivery.¹³ The results are reported in table 3 and table 4 for the base and peak futures, respectively. Standard errors are calculated autocorrelation and heteroscedasticity robust using the Newey-West estimator. The standard deviation and the t-value are reported as well.

- Include table 3 about here -

The risk premia exhibit a similar behaviour for both the base and peak futures. After reaching a maximum in the two month future a decrease with increasing time-to-delivery is observed. The risk premium in the one month base future is significant at the 10% level. For the peak futures the risk premium in the one month future is significant at the 5% level and in the two month future at the 10% level. In futures with longer time-to-delivery the risk premia are not statistically significant.

The obtained results confirm our hypothesis that electricity consumers seem to use mainly short-term futures for hedging purposes. We also assume that the observed decrease of

¹³ All estimations are also performed on the daily data. The results are similar to the results on monthly data except lower standard errors due to the autocorrelation.

the risk premia, after reaching a maximum in the two month future, with increasing time-to-delivery reflects the decreasing demand from electricity consumers. This effect will be further analysed below.

- Include table 4 about here -

The estimated relative risk premium accounts for 3% of the price of the one month base future and for 5% of the month peak future. Compared to other futures markets this is a relatively large risk premia which the market participants are willing to pay for the disposal of price risk for a time horizon of one month. Figure 3 shows the evolution of the relative risk premia in the one month base and peak future during our sample period.

- Include figure 3 about here -

In figure 3 it can be seen that forecast errors result in partially dramatic discrepancies between future and realised spot prices. These discrepancies are by far greater than the estimated average risk premia, thus the volatility of the risk premia is very high. Further research has to be done when a longer sample period is available.¹⁴

By analysing the daily data further support for the hypothesis of decreasing risk premia with increasing time-to-delivery is obtained. We compute the absolute risk premia for every daily observation and synchronize the calculated risk premia according to the first day of the delivery month. This allows us to sort all the obtained risk premia according to days-to-delivery. The results of this computation are found in figure 4 for the base futures and in figure 5 for the peak futures.

- Include figure 4 about here -

In both figures every data point is calculated on average from 50 separate observations. For a better visualisation a moving average over seven days is also shown in the figure. The high volatility is due to weekend effects.

- Include figure 5 about here -

¹⁴ Another interesting research question which can not be answered with the available dataset is the evolution of risk premia over time. The market entry of new market participants should – at least from a theoretical point-of-view - lead to a more efficient market and thus to a decrease of the risk premia.

The results in figure 4 and 5 support the hypothesis of decreasing risk premia with increasing time-to-delivery. After reaching a maximum in the region of 60 to 70 days-to-delivery the risk premia are subsequently decreasing with increasing time-to-delivery. In the case of base futures we even observe a change of sign at the end of the term structure. Unfortunately our dataset does not include long-term futures to test whether this change of sign is systematic and due to market segmentation caused by different risk preferences.

We run the following regression to capture the behaviour of risk premia depending on days-to-delivery (DTD)

$$\pi_i(T) = a + b \cdot DTD_i^2 + c \cdot DTD_i . \quad (8)$$

The results of this regression are reported in table 5. In addition to the coefficients we also report the adjusted R². As expected, the coefficient of the quadratic part of equation (8) is negative.

- Include table 5 about here -

Shawky et al. (2003) were the first to report results on the relationship between risk premia and time-to-delivery. For the years 1998 and 1999 they find a linear increasing risk premium with increasing time-to-delivery for the California-Oregon Border area. On the other side, Diko et al. (2006) find positive short-term and negative long-term risk premia in OTC forward prices for three European futures markets. Decreasing risk premia with increasing time-to-delivery are reported by Marckhoff and Wimschulte (2009) for the Nord Pool market. Weron (2008) finds the same effect by modelling the market price of risk for the Scandinavian area through stochastic models. Benth et al. (2008) develop a theoretical model to explain this effect.

Time variation is another interesting aspect regarding risk premia. Lucia and Torro (2008) find seasonality in risk premia at the Nord Pool. Their results indicate that risk premia are highest and statistically significant for delivery periods in winter and zero for delivery periods in summer. Cartea and Villaplana (2008) model the size and sign of risk premia depending on demand and capacity. One implication of their model are positive risk premia caused by high volatility of demand. This implies positive risk premia in winter months. The model of Bessembinder and Lemmon (2002) also suggests seasonality in risk premia caused by demand uncertainty.

Due to the lack of a sufficient sample period we cannot directly test for seasonality in our data. We only have six futures with delivery in a particular month meaning that only six independent expectation building processes regarding a particular calendar month took place. To overcome this problem we calculate the risk premia contained in every future contract. The results for base futures are reported in table 6.

- Include table 6 about here -

Almost every risk premium reported in table 6 is significant at the 1% level. The calculated risk premia exhibit a high variability both in magnitude and sign. However, due to the fact that we analyse single contracts, the differences between the futures and the realized spot price have rather to be interpreted more as forecast errors than as risk premia. We therefore report in the last column the average for every particular month. Evidence for seasonality is found when comparing the averages. Positive risk premia are observed in winter months, especially in December and January. After a decrease in spring and autumn the summer months are characterised by negative risk premia. However, no statistical verification of these results is possible. The results are confirmed by similar results for the peak futures reported in table 7.

- Include table 7 about here -

Using the resultant data on the risk premia in the individual future contracts we run a regression to test whether the risk premia in base and peak futures are the result of similar expectation building processes. We therefore regress the realised risk premia in peak futures, π_{Peak} , on the realised risk premia in base futures, π_{Base} .

$$\pi_{Peak,i}(T) = a + b \cdot \pi_{Base,i}(T) \quad (9)$$

As result we obtain an estimated slope coefficient of 1.67 and a R² of 93.6 percent. The relation in (9) thus seems to fit the data well. We conclude that market participants do not forecast base and peak prices independently.

4.3 What Drives Risk Premia?

The results in the previous section provide evidence for the presence of risk premia in the German electricity futures market. This section is dedicated to the discussion of potential drivers. Our analysis focuses on whether the existence of risk premia can be linked to risk

considerations. Possible fundamental drivers are discussed qualitatively. The quantitative verification is left for further research.

The model of Bessembinder and Lemmon (2002) identifies the third and fourth moment of realised spot prices as drivers of the risk premia. The relation to test is

$$\pi_i(T) = a + b \cdot VAR_i[S(T)] + c \cdot SKEW_i[S(T)] \quad (10)$$

with VAR being the variance and SKEW the skewness of the realised daily spot prices during the delivery period. The skewness is in this case non-standardised. According to Bessembinder and Lemmon (2002) a negative relation between variance and risk premia as well as a positive relation between skewness and risk premia is to expect.

We regress both the month base and month peak futures prices on the third and fourth moment of the spot prices and report the results in table 8. Almost all coefficients of the regression are significant at the 1% level and have the expected sign. This appears to be convincing evidence for the practicability of the Bessembinder and Lemon model and supports the assumption that risk premia in the German electricity future market are linked to risk considerations.

- Include table 8 about here -

Similar results were also reported by Longstaff and Wang (2004) for the PJM day-ahead market and Furio and Meneu (2009) for the Spanish futures market. Lucia and Torro (2008) report mixed results for the Nord Pool futures where the dependence holds before a shock period and vanishes thereafter. Marckhoff and Wimschulte (2009) find support for the model using data from the Nord Pool futures market. The mixed results reported in the literature suggest that other drivers may be relevant as well.

Fundamental factors can also serve as drivers of the risk premia. Only a few results have been reported to date. Douglas and Popova (2008) for example link risk premia and gas storage inventories. The authors develop a model which links increasing gas storage inventories under realistic assumptions to a decrease of the risk premia. That is explained by a decreasing probability for the occurrence of price spikes. Daskalakis and Markellos (2009) link risk premia and emission allowance spot prices. They empirically demonstrate a positive relationship, among others with data from the EEX.

5. Conclusion

We conduct an in-depth analysis of the German electricity futures market in this paper. The primary aim is to test whether risk premia caused by hedging pressure can be found. Due to liquidity considerations we restrict our analysis to month futures. Our analysis yields some interesting results. First, we find evidence for positive risk premia in short-term futures. Second, we show that after a rise at the beginning, the risk premia decrease with increasing time-to-delivery. Third, we detect evidence for seasonality in the risk premia. The risk premia seem to be positive for delivery months in winter and zero or even negative in summer. Fourth, we show that the risk premia are linked to risk considerations.

The obtained results are consistent with theoretical and empirical literature. They support the hypothesis that hedging pressure is an appropriate approach for understanding the price formation in the German electricity futures market. The short-term futures seem to be used mainly by electricity consumers for hedging purposes. With increasing time-to-delivery the demand of electricity consumers seems to decrease. This results in low and statistically insignificant risk premia in the mid-term futures. The question whether the risk premia change sign and thus whether a market segmentation is apparent can not be answered due to the shortness of the sample period.

Based on our results, future research in at least two directions seems to be promising. First, further analysis on the role of forecast errors is necessary. The quantification of possible forecast errors would contribute to the interpretation of the estimated price differences between futures and realised spot prices. Second, an identification of fundamental drivers for the risk premia also seems to be promising. The role of fuels (coal, gas and oil) and of emission allowances is here of particular interest.

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Figure 1
Traded Contracts Month Futures

Average number of daily traded contracts with respect to time-to-delivery. Considered are only month futures with a time-to-delivery of up to six months. The futures are synchronized according to the delivery month. Every point in the figure represents the average of at least 47 observations. The straight line represents the month base futures, the dashed line the month peak futures.

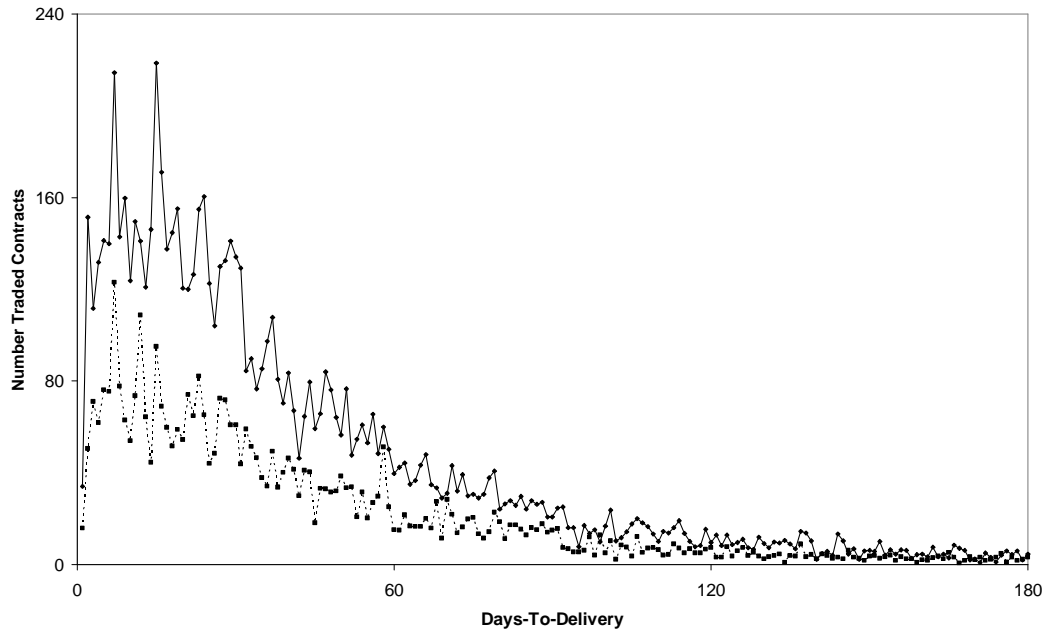


Figure 2
Monthly Prices Spot Market

Monthly prices on the day-ahead market. The monthly prices are calculated as the arithmetic average of hourly prices.
The straight line represents the monthly Phelix Base, the dashed line the monthly Phelix Peak.

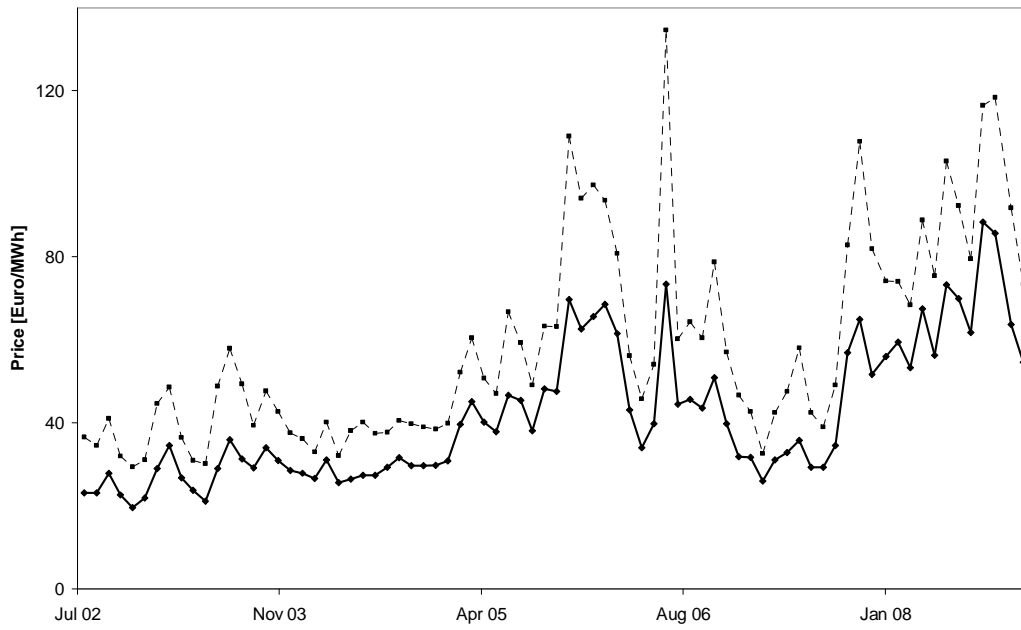


Figure 3
Relative Risk Premia In One Month Future

Relative risk premia in the one month future with respect to the futures price. The straight line represents the month base future, the dashed line the month peak future.

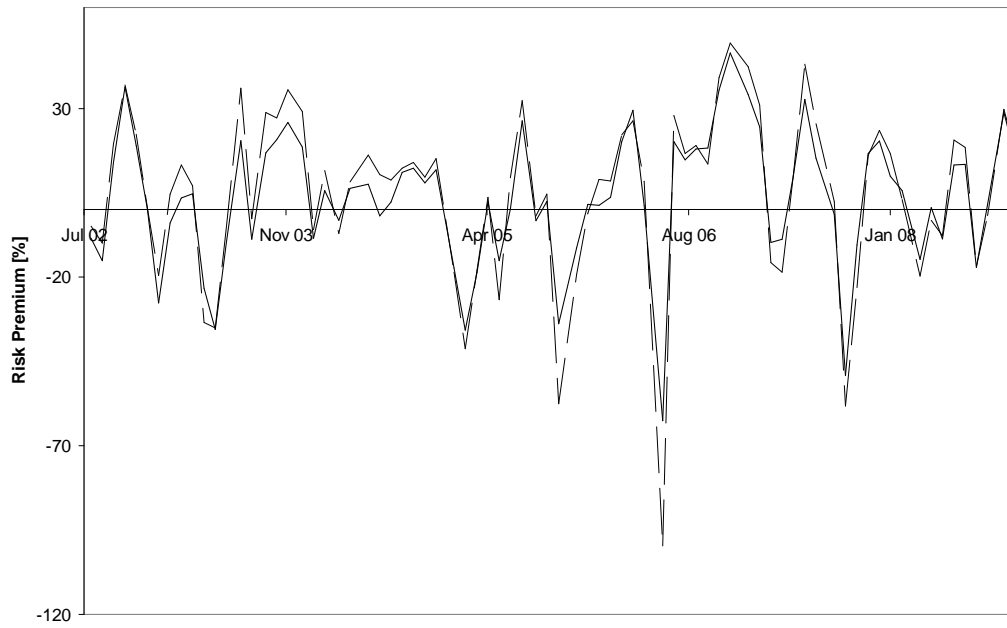


Figure 4
Risk Premia In Month Base Futures By Time-To-Delivery

Risk premia in the month base futures with respect to time-to-delivery. The futures are synchronized according to the delivery month. Every point is calculated as the average of 42 to 53 observations. In addition for graphical reasons a moving average over seven days is also shown (straight line).

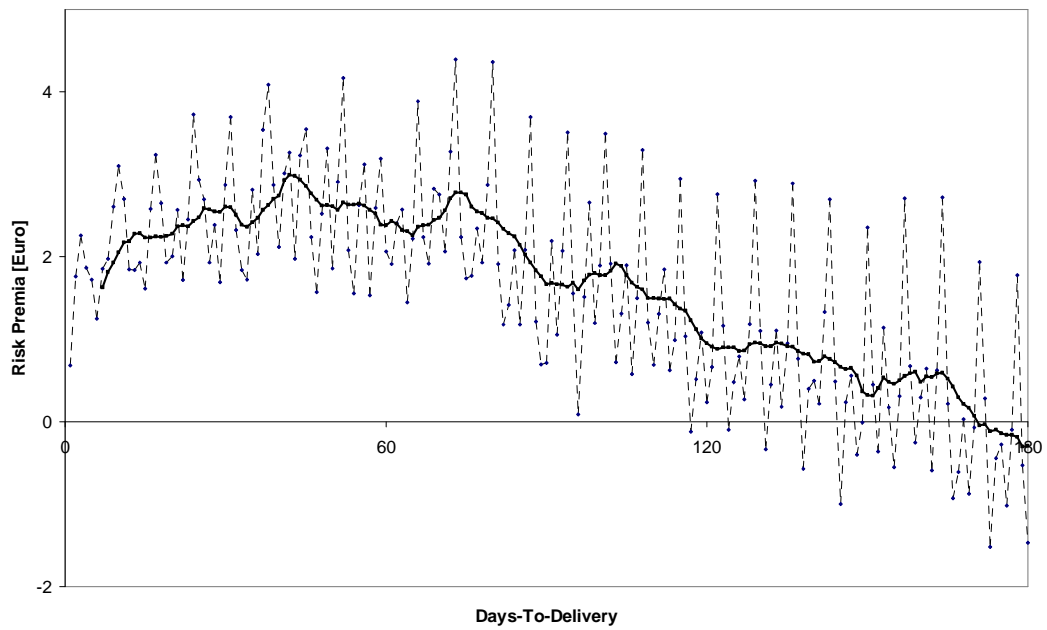


Figure 5
Risk Premia In Month Peak Futures By Time-To-Delivery

Risk premia in the month peak futures with respect to time-to-delivery. The futures are synchronized according to the delivery month. Every point is calculated as the average of 42 to 53 observations. In addition for graphical reasons a moving average over seven days is also shown (straight line).

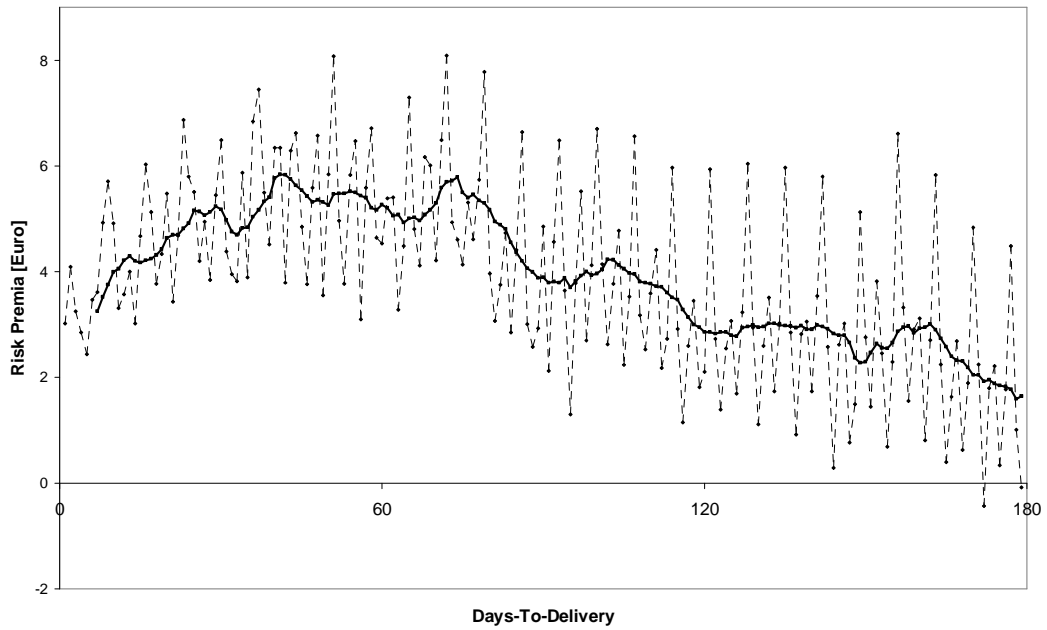


Table 1
Descriptive Statistics Month Base Futures

The first table contains descriptive statistics on the price data, the second on the return data (computed as log returns). The data are monthly. Descriptive statistics for the corresponding daily data are reported in brackets. Price data in Euro, return data in %.

Future	# Obs.	Mean	Std.Dev.	Minimum	Median	Maximum	Skewness	Kurtosis
One	78	44,25	16,77	21,31	38,41	89,46	0,72	-0,34
	(1644)	(44,24)	(16,93)	(20,8)	(39,07)	(98,41)	(0,76)	(-0,26)
Two	78	45,25	17,22	22,33	41,56	92,79	0,65	-0,45
	(1644)	(45,22)	(17,32)	(21,48)	(40,97)	(96,76)	(0,68)	(-0,38)
Three	78	45,61	17,68	21,68	41,68	91,75	0,77	-0,11
	(1644)	(45,69)	(17,78)	(21,22)	(41,61)	(98,23)	(0,79)	(-0,07)
Four	78	45,59	17,74	21,18	42,22	95,44	0,87	0,3
	(1644)	(45,68)	(17,82)	(20,8)	(42,28)	(101,94)	(0,89)	(0,33)
Five	78	45,56	17,75	21,3	43,39	96	0,88	0,47
	(1644)	(45,67)	(17,83)	(20,93)	(43,35)	(101)	(0,9)	(0,48)
Six	78	45,47	17,42	20,5	42,47	95,32	0,82	0,39
	(1644)	(45,54)	(17,48)	(20,35)	(42,43)	(102,75)	(0,84)	(0,4)

One	77	1,26	13,55	-33,7	2,77	43,26	-0,05	0,65
	(1643)	(0,62)	(32,57)	(-154,74)	(-0,61)	(275,85)	(1,77)	(15,07)
Two	77	1,24	13,15	-38,48	1,5	32,82	-0,14	0,42
	(1643)	(0,59)	(26,39)	(-180,49)	(0)	(248,25)	(1,07)	(17,77)
Three	77	1,02	13,25	-35,68	1,68	43,93	0,05	1,05
	(1643)	(0,46)	(25,65)	(-239,07)	(0)	(321,77)	(1,96)	(38,97)
Four	77	0,83	11,26	-34,73	1,69	31,46	-0,41	1,21
	(1643)	(0,38)	(23,99)	(-199,7)	(0,41)	(336,7)	(0,98)	(45,7)
Five	77	0,82	10,83	-27,36	1	27,86	-0,07	0,13
	(1643)	(0,37)	(23,26)	(-222,47)	(0)	(307,48)	(1,33)	(43,02)
Six	77	0,85	10,33	-23,11	0,78	24,16	-0,26	0
	(1643)	(0,4)	(22,71)	(-205,07)	(0)	(278,37)	(0,46)	(37,21)

Table 2
Descriptive Statistics Month Peak Futures

The first table contains descriptive statistics on the price data, the second on the return data (computed as log returns). The data are monthly. Descriptive statistics for the corresponding daily data are reported in brackets. Price data in Euro, return data in %.

Future	# Obs.	Mean	Std.Dev.	Minimum	Median	Maximum	Skewness	Kurtosis
One	78	63,01	23,5	32,49	57,62	130,77	0,74	-0,29
	(1644)	(63,02)	(23,95)	(31,55)	(56,56)	(141,56)	(0,8)	(-0,16)
Two	78	64,94	24,21	33,34	61,79	131,4	0,64	-0,53
	(1644)	(64,88)	(24,44)	(32,14)	(60,9)	(136,91)	(0,69)	(-0,43)
Three	78	65,41	24,65	31,9	64,81	130,11	0,78	-0,11
	(1644)	(65,51)	(24,85)	(31,5)	(63,23)	(139)	(0,81)	(-0,07)
Four	78	65,27	24,5	31,24	63,92	131,08	0,89	0,34
	(1644)	(65,4)	(24,65)	(30,68)	(63,97)	(143)	(0,91)	(0,36)
Five	78	65,29	24,29	31,21	61,93	131,3	0,86	0,34
	(1644)	(65,43)	(24,41)	(30,88)	(61,35)	(143)	(0,87)	(0,32)
Six	78	65,31	23,91	30,61	62,47	134,19	0,83	0,35
	(1644)	(65,39)	(24,02)	(30,25)	(62,41)	(144,1)	(0,84)	(0,34)

One	77	1,11	17,42	-44,87	2,25	51,38	0	0,8
	(1643)	(0,57)	(41,84)	(-226,3)	(-1,29)	(437,22)	(1,92)	(19,48)
Two	77	1,17	15,89	-47,23	1,17	49,45	0,1	1,22
	(1643)	(0,56)	(31,66)	(-213,09)	(0)	(395,86)	(2,12)	(28,33)
Three	77	0,94	14,73	-39,01	1,62	35,53	-0,25	0,33
	(1643)	(0,44)	(28,5)	(-315,52)	(0,51)	(358,18)	(0,77)	(40,3)
Four	77	0,73	12,14	-38,11	1,41	27,22	-0,69	0,86
	(1643)	(0,32)	(26,6)	(-298,76)	(0,24)	(240,81)	(-0,32)	(40,74)
Five	77	0,74	11,56	-30,05	-0,98	25,6	-0,01	-0,05
	(1643)	(0,34)	(24,79)	(-289,47)	(0)	(262,86)	(0,37)	(37,91)
Six	77	0,79	10,82	-29,64	1,66	22,17	-0,38	0,07
	(1643)	(0,37)	(22,48)	(-252,79)	(0,15)	(174,64)	(-1,23)	(35,46)

Table 3
Risk Premia In Month Base Futures

The first table contains results on the absolute risk premia, the second on the relative (with respect to the futures price) risk premia.
***, ** and * indicates significance at the 1, 5 and 10 % level; the Newey-West estimator was used in order to obtain robust standard errors.

Maturity	Mean	t-value	Std.Dev.	Mean	t-value	Std.Dev.
One	2,3*	1,86	9,26	3,49	1,35	19,75
Two	2,68	1,45	11,97	2,93	0,80	24,43
Three	2,34	1,07	12,73	2	0,46	25,19
Four	1,54	0,65	13,08	0,28	0,06	25,83
Five	0,73	0,29	13,50	-1,7	-0,34	26,52
Six	-0,03	-0,01	13,79	-3,61	-0,67	27,77

Table 4
Risk Premia In Month Peak Futures

The first table contains results on the absolute risk premia, the second on the relative (with respect to the futures price) risk premia.
***, ** and * indicates significance at the 1, 5 and 10 % level; the Newey-West estimator was used in order to obtain robust standard errors.

Maturity	Mean	t-value	Std.Dev.	Mean	t-value	Std.Dev.
One	4,36**	2,04	17,09	5,05	1,62	25,23
Two	5,45*	1,77	21,30	4,96	1,17	30,28
Three	4,95	1,42	21,75	4,24	0,88	30,37
Four	3,78	1,03	21,52	2,87	0,47	29,99
Five	2,82	0,74	21,55	1,48	0,79	30,18
Six	1,97	0,48	22,24	-0,15	-0,03	32,33

Table 5
Regression Risk Premia On Time-To-Delivery

Results for the regression of the risk premia on days-to-delivery.

***, ** and * indicates significance at the 1, 5 and 10 % level; the Newey-West estimator was used in order to obtain robust standard errors.

	a	b	g	Adj. R ² [%]
Base	2,2678***	-0,0001***	0,0092*	50,04
Peak	4,269*	-0,0002***	0,022**	34,28

Table 6
Risk Premia In Month Base Futures By Delivery Period

Risk premia in the individual future contracts over their whole trading period. The values in brackets are standard errors.

***, ** and * indicates significance at the 1, 5 and 10 % level; the Newey-West estimator was used in order to obtain robust standard errors.

Delivery Period	2003	2004	2005	2006	2007	2008	All
January	-0,8*** (0,19)	8,34*** (0,76)	6,85*** (0,35)	-12,33*** (1,26)	35,86*** (0,81)	10,37*** (0,96)	8,05
February	-6,74*** (0,13)	9,49*** (0,66)	-2,76*** (0,4)	-12,7*** (1,55)	32,99*** (1,61)	8,02*** (0,91)	4,72
March	-2,15*** (0,14)	0,16 (0,43)	-11,1*** (0,29)	-7,13*** (1,38)	27,47*** (1,96)	5,84*** (0,43)	2,18
April	0,06 (0,1)	3,7*** (0,3)	-7,65*** (0,2)	7,25*** (0,95)	9,47*** (1,64)	-10,72*** (0,37)	0,35
May	0,42*** (0,14)	0,28 (0,24)	-6,03*** (0,66)	13,67*** (0,84)	1,71 (1,04)	-2,58*** (0,41)	1,24
Jun	-6,45*** (0,12)	2,48*** (0,26)	-11,81*** (0,81)	11,05*** (1,13)	4,57*** (0,84)	-12,71*** (0,8)	-2,14
July	-12,86*** (0,35)	1,71*** (0,15)	-8,33*** (1,14)	-22,26*** (1,01)	15,78*** (0,86)	-1,31 (1,41)	-4,55
August	-7,7*** (0,53)	-0,55*** (0,16)	2,14 (1,51)	7,1*** (1,08)	10,93*** (0,79)	2,93** (1,24)	2,47
September	-0,42 (0,86)	-0,5** (0,23)	-4,43*** (1,16)	8,76*** (0,8)	5,45*** (0,76)	-15,24*** (1,58)	-1,06
October	-4,66*** (0,41)	3,24*** (0,14)	-2,11*** (0,78)	11,13*** (0,75)	-16,12*** (0,56)	-6,94*** (1,66)	-2,58
November	1,72*** (0,47)	6,44*** (0,25)	-21,49*** (0,73)	13,59*** (0,84)	-14,02*** (1)	25,73*** (1,1)	2,00
Decemeber	3,7*** (0,61)	5,08*** (0,26)	-12,98*** (0,8)	23,72*** (0,65)	-0,93 (1,43)	28,07*** (1,79)	7,78
All	-2,99	3,32	-6,64	3,49	9,43	2,62	

Table 7
Risk Premia In Month Peak Futures By Delivery Period

Risk premia in the individual future contracts over their whole trading period. The values in brackets are standard errors.

***, ** and * indicates significance at the 1, 5 and 10 % level; the Newey-West estimator was used in order to obtain robust standard errors.

Delivery Period	2003	2004	2005	2006	2007	2008	All
January	-2,69*** (0,39)	20,58*** (1,15)	13,35*** (0,84)	-23,59*** (2,13)	53,14*** (0,87)	17,77*** (1,62)	13,09
February	-7,14*** (0,24)	22,76*** (1,25)	-1,19 (0,93)	-15,5*** (2,66)	53,47*** (2,1)	18,78*** (1,58)	11,86
March	0 (0,23)	5,01 (0,79)	-14,6*** (0)	-6,19*** (2,08)	47,32*** (3,24)	10,16*** (0,88)	6,95
April	3,82 (0,17)	10,83*** (0,9)	-6,88*** (0,42)	12,71*** (1,52)	15,19*** (2,64)	-15,56*** (0,41)	3,35
May	1,62*** (0,2)	1,96** (0,83)	-4,72*** (0,69)	17,94*** (1,01)	1,62 (2,06)	-5,09*** (0,41)	2,22
Jun	-13,03*** (0,13)	5,02*** (0,67)	-19,51*** (0,79)	17,79*** (1,45)	3,21*** (1,38)	-18,44*** (1,24)	-4,16
July	-21,85*** (0,69)	5,83*** (0,47)	-8,55*** (1,76)	-61,18*** (1,07)	31,79*** (2,13)	6,03 (2,09)	-7,99
August	-12,08*** (1,09)	4,54*** (0,39)	5,59 (2,4)	14,76*** (1,38)	26,2*** (1,85)	12,13*** (1,81)	8,52
September	4,66 (1,99)	3,56** (0,38)	-4,27*** (1,98)	12,9*** (1,1)	14,95*** (1,85)	-14,95*** (2,39)	2,81
October	-4,09*** (0,97)	6,61*** (0,25)	-1,67 (1,34)	18,13*** (1,04)	-21,04*** (1,5)	-10,11*** (2,35)	-2,03
November	9,35*** (0,92)	11,93*** (0,53)	-43,62*** (1,14)	15,1*** (0,83)	-30,14*** (1,74)	35,48*** (1,7)	-0,32
Decemeber	10,36*** (0,91)	10,18*** (0,66)	-25,84*** (1,33)	36,69*** (0,72)	-3,57 (2,43)	40,69*** (2,44)	11,42
All	-2,59	9,07	-9,33	3,30	16,01	6,41	

Table 8
Regression Risk Premia On Variance and Skewness Of Spot Prices

Regression of risk premia on variance and skewness of spot prices. The data are monthly and the skewness is unnormalised.
 ***, ** and * indicates significance at the 1, 5 and 10 % level; the Newey-West estimator was used in order to obtain robust standard errors.

Base					
Future	# Obs.	a	b	c	Adj. R ² [%]
One	77	4,624766***	-0,011257*	0,000009	20,35
Two	76	6,595506**	-0,021244**	0,000065	20,89
Three	75	6,950536***	-0,026997***	0,00012***	18,01
Four	74	6,109413**	-0,026717***	0,000123**	16,82
Five	73	5,310879*	-0,026541***	0,000123***	14,73
Six	72	4,947535	-0,028913***	0,000136**	16,55

Peak					
One	77	10,51756***	-0,014004***	0,000023**	39,03
Two	76	14,35577***	-0,021663***	0,000045***	39,51
Three	75	14,50248***	-0,023822***	0,000054***	38,37
Four	74	12,64143***	-0,021733***	0,000048***	33,66
Five	73	11,7191***	-0,021601***	0,000049***	32,41
Six	72	11,4604***	-0,02303***	0,000052***	34,92