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Anatomy of Risk Premium in UK Natural Gas Futures

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Summary

In many futures markets, trading is concentrated in the front contract and positions are rolled-over until the strategy horizon is attained. In this paper, a pair-wise comparison between the conventional risk premium and the accrued risk premium in rolled-over positions in the front contract is carried out for UK natural gas futures. Several novel results are obtained. Firstly, and most importantly, the accrued risk premium in rollover strategies is significatively larger than conventional risk premiums and increases with the time to delivery. Specifically, for strategy horizons between three and six months, this difference increases from 1% to 10%. Secondly, it is the first time that risk premium in day-ahead futures has been measured in this market. The average value of the day-ahead risk premium is 0.5% per day and it is statistically significant. Thirdly, all risk premiums are significantly larger and more volatile in winter. Finally, risk premium time-variation is analyzed using a regression model. It is shown that reservoirs, weather, liquidity, volatility, skewness, and seasons are able in all cases to explain between 21% and 59% of the risk premium time-variation (depending on the futures maturity and sub-period).

Keywords: Natural Gas Market, Futures Premium, Rollover, Seasonal Risk Premiums

JEL Classification: G13, L95

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Anatomy of risk premium in UK natural gas futures*

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Anatomy of risk premium in UK natural gas futures

Abstract

In many futures markets, trading is concentrated in the front contract and positions are rolled-over until the strategy horizon is attained. In this paper, a pair-wise comparison between the conventional risk premium and the accrued risk premium in rolled-over positions in the front contract is carried out for UK natural gas futures. Several novel results are obtained. Firstly, and most importantly, the accrued risk premium in rollover strategies is significatively larger than conventional risk premiums and increases with the time to delivery. Specifically, for strategy horizons between three and six months, this difference increases from 1% to 10%. Secondly, it is the first time that risk premium in day-ahead futures has been measured in this market. The average value of the day-ahead risk premium is 0.5% per day and it is statistically significant. Thirdly, all risk premiums are significantly larger and more volatile in winter. Finally, risk premium time-variation is analyzed using a regression model. It is shown that reservoirs, weather, liquidity, volatility, skewness, and seasons are able in all cases to explain between 21% and 59% of the risk premium time-variation (depending on the futures maturity and sub-period).

***JEL* Classification**: G13 and L95.

Keywords: natural gas market, futures premium, rollover, and seasonal risk premiums.

Anatomy of risk premium in UK natural gas futures

1. Introduction

In many futures markets, trading is concentrated in the front contract and positions are rolled-over until the strategy horizon is attained. This is especially true for British National Balancing Point (NBP) futures because trading is concentrated on those contracts closest to maturity, and especially in the front contract. UK natural gas futures is the European benchmark for natural gas and the front contract seem to lead the remaining European natural gas futures and spot markets.[1] Futures negotiated at the Intercontinental Exchange (ICE) are increasing in importance and liquidity – and represent more than one-third of all traded gas negotiated at NBP (Heather, 2010).

Risk premium can be seen as the expected returns of holding until delivery a short position in a futures contract. For long-term strategies, positions can be taken in long-term maturity futures; or alternatively, short-term maturity futures can be rolled over until the strategy horizon is attained. Before making a decision, a portfolio manager takes into account the transaction costs incurred in each alternative and the usual trade-offs existing between the use of long-term maturity futures that exactly fit the desired planning horizon and the higher liquidity of short-term maturity futures. The more innovative aim of this paper is to measure the accrued risk premium in a rolled-over position in short-term maturity futures in the UK natural gas market in order to obtain a pair-wise comparison with each corresponding long-term conventional risk premium. Conventional long-term and accrued short-term risk premiums differ as each is related to different risk factors. Accrued

[1] Price discovery has been studied in Schultz and Swieringa (2013), using intraday data of futures and spot prices (NBP, ZEE and TTF). NBP spot in the short run and ICE prompt in the short and long run are leading the equilibrium. It is also found that spot markets are weakly linked and this suggests significant market frictions may exist between the various natural gas hubs in Europe. Results in Kao and Wan (2009) show that NBP futures prices lead spot prices – both in mean and volatility.

short-term risk premiums will be closely related with the spot price risk while the long-term premiums mainly reflect the risk present in the convenience yield (Szymanowska et al. (2014)).[2]

Therefore, obtaining an exact measure of risk premiums for both alternatives is an insightful piece of information for agent decision making. But further to this, it is important information when analyzing time-variation in both cases. We study the seasonal pattern in both cases and we estimate a regression model reflecting risk premium response to risk factors. If risk factors are able to explain time-varying realized risk premiums it can be understood that an important part of expected risk premiums are priced according to risk considerations – and not priced by a simple bias obtained as a result of some agents dominating the market.

Mu (2007), Suenaga et al. (2008) and Alterman (2012) report several features of natural gas price volatility. The most relevant result for our study is that volatility is seasonal and closely related with weather shocks and storage levels. The reason for this comes from the fact that demand seasonality is closely related with weather seasonality. In winter demand jumps are more difficult to buffer because the active storage management is less flexible due to high marginal cost production and demand inelasticity. Our intuition extracted from previous literature on natural gas prices is that risk premiums on futures prices probably contain a strong seasonal pattern.[3]

As far as we know, the only published paper studying risk premiums in the UK natural gas futures market is Haff et al. (2008). This study is more focused on explaining convenience yield, spread between futures contracts and basis. The only result on risk premiums in this bibliographical

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[2] Using energy futures traded at NYMEX (heating oil, gasoline, and crude oil) for the period March 1986 to December 2010, Szymanowska et al. (2014) obtain annualized risk premiums slightly above the accrued risk premiums in the rollover strategy when taking values of about 10% for all the analysed maturities. Differences between both premiums were not significant.

[3] Nevertheless, we have to mention that price seasonality of natural gas in the US is decreasing sharply. Non-conventional shale gas is abundant and represents a downward pressure on winter prices. Furthermore, the increased number of cooling systems and the growing use of natural gas are raising summer prices (see Henaff et al. (2013)). We believe this phenomenon is not yet as important in European countries.

reference is that risk premiums vary between 5% and 8% (1 to 5 months ahead) using 75 monthly observations for each maturity.[4]

Several empirical contributions are produced in this paper. Firstly, all risk premium average values are significantly different to zero, positive, and increasing with time to delivery. Most importantly, the accrued risk premium in rollover strategies is significatively larger than conventional risk premiums and increases with time to delivery. Specifically, for strategy horizons between 3 and 6 six months, this difference increases from 1% to 10%. We have also shown that these differences can be partially explained by liquidity arguments in the futures market. Secondly, it is the first time that risk premium in day-ahead futures has been measured in this market. The average value of the day-ahead risk premium is 0.5% per day and this is statistically significant. Thirdly, all risk premiums are significantly larger and more volatile in winter. The significant and highest monthly values correspond to January and February. Finally, risk premium time-variation is analyzed using a regression model. It is shown that reservoirs, weather, liquidity, volatility, skewness, and seasons are in all cases able to explain between 21% and 59% of risk premium time-variation – depending on the futures maturity and sub-period.

The reminder of this paper is organized as follows. Section 2 summarizes the risk premium approach to futures pricing, and describes the general features of the empirical research carried out in this paper. Section 3 describes the data set used in the empirical application. Section 4 describes the results obtained. Section 5 concludes with a summary of the main results and some final remarks.

2. The risk premium approach

[4] Risk premiums are measured by comparing the futures price near to maturity with the futures prices taken 1 to 5 months before that maturity. The underlying spot price when the risk premiums are computed is not taken into account. As we use the true underlying spot price, we use futures with one to six months to delivery. In this way, for example, the three months to maturity in Haff et al. (2008) risk premium can be obtained by subtracting one to four months from delivery risk premiums. We have checked this computation in our data set and it is about the same.

Following Fama and French (1987) and Lucia and Torro (2011), we review some basic well-known definitions and relate this classical view with the innovative approach to futures pricing in Szymanowska et al. (2014). Under the risk premium approach to futures pricing, the futures price is split into the expected spot price on the delivery date and a premium, which is variously known as the risk premium, the futures or forward premium, and the futures or forward bias. To fix notation, let $S(t)$ denote the spot price for natural gas to be delivered at time *t*, let $F(t-j,t)$ denote the futures price observed *j* days/months before *t* when the natural gas is due to be delivered, and let $P(t-j,t)$ denote the risk premium. The basic futures pricing relationship under the risk premium approach can be written as follows:

$$F(t-j,t) = E_{t-j}\left[S(t)\right] + P(t-j,t) \tag{1}$$

where $E_{t-j}[\cdot]$ denotes the conditional expectation operator at time $t-j$. The above-defined premium is also called the *ex ante* or expected premium, to be distinguished from the *ex post* or realized premium, which is defined as the difference between the futures price and the spot price at maturity:

$$RP(t-j,t) = F(t-j,t) - S(t) \tag{2}$$

Adapting the definition in Szymanowska et al. (2014), the expected rollover premium can be written as

$$ROP(t-j,t) = E_{t-j}[F(t-1,t) - S(t)] + \sum_{k=1}^{j-1} E_{t-j}\left[F(t-(k+1), t-(k-1)) - F(t-k, t-(k-1))\right] \tag{3}$$

for j = 3, 4, …, n months before delivery. Realized rollover premiums will be computed by taking realized prices instead of expected prices. In the above equation, we have added the first term $E_{t-j}[F(t-1,t)-S(t)]$, as in Szymanowska et al. (2014) risk premiums are calculated on futures maturity and not on the delivery date, when the true underlying price is known. The second term is the summation of all the one month premiums accrued in the rollover strategy in the front contract. Note that in our notation, "t–1" is the last trading day of the futures contract considered and 't' corresponds to the delivery day or month. The first rollover will appear with j = 3, that is, three months before the delivery date 't'. Therefore, for one and two months before delivery, only conventional risk premiums can be computed. In this way, the one month before delivery date will correspond to the front futures contract maturity date, and the two months before the delivery date will match the last date in which a futures position is opened in a rollover strategy, consequently no further risk-premium accumulation is possible. The day-ahead risk premium will be computed as the difference between the average of day-ahead futures and the average of the system average price within each month.

But further to this, it is important to analyze time-variation in both cases. To provide compelling evidence of time-varying expected premiums, we will estimate a regression model reflecting seasonal and risk premium response to risk factors without imposing a specific structure implied by an equilibrium model. If risk factors are able to explain time-varying realized risk premiums it can be understood that an important part of expected risk premiums are priced according to risk considerations and not a simple bias without economic significance. The regression model we propose is the following

$$\begin{aligned} F(t-j,t)-S(t) &= aWinter + bSummer + cSD(t-j) + dSkew(t-j) + eVol(t-j) \\ &\quad + fOI(t-j) + gUHDD(t-j) + hEU(t-j) + iUK(t-j) + \varepsilon(t-j,t) \end{aligned} \tag{4}$$

for j = 1 *day*, 1, 2, 3, 4, 5 and 6 months to delivery. *Winter* and *summer* are dummies for the seasons. Winter season is defined by taking the following months: October, November, December, January, February and March. The remaining months are taken for the summer season. *SD* and *Skew* refer to the standard deviation and the unstandardised skewness within each month of the daily *system average price*.[5] *Vol* and *OI* refer to the monthly average of the daily traded volume and open interest of each futures contract. *UHDD* represent the difference between the historical value and the observed daily accrued heating degree days for each month within the year for the United Kingdom. *EU* and *UK* refer to the natural gas reservoir levels in the European Union and the United Kingdom, respectively. For the day-ahead futures, the dependent variable is computed in each month as the average value of $F(t-1\,day, t) - S(t)$ within each month (as we are using monthly data frequency). Equation (4) will be also estimated for rollover realized premiums in order to obtain the special features of this pricing approach. Finally, regression in Equation (4) will be carried out on the difference between realized accrued rollover premiums and conventional realized risk premiums.

Natural gas demand has a clear seasonal pattern related to weather variables (temperature, wind speed, humidity and precipitation). Prices will respond to this pattern and especially to any surprises relative to historical values.[6] To this end, the difference between the accrued *heating degree days* for each month and its historical average since 1974 for the UK is used.

The introduction of storage levels to explain risk premium dynamics is crucial. The influence of storage levels in natural gas futures prices and volatility has been studied by Efimova and Serletis (2014), Suenaga et al. (2008), Mu (2007), Henaff (2013) and Wei and Zhu (2006). Storage level seasonality influences on natural gas spot and futures pricing is crucial. Under the theory of storage, inventory seasonalities generate seasonalities in the marginal convenience yield –

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[5] Motivated by findings by Bessembinder and Lemmon (2002) in electricity markets, some basic characteristics of the time variation in risk premiums are consistent with equilibrium. Bessembinder and Lemmon (2002) proved that the expected forward premium is linearly related (negatively) to the variance of the delivery-date spot price and (positively) with the unstandardised skewness of the spot price. Furthermore, these authors show that seasonal patterns in risk premiums can be consistent with the equilibrium model they propose.

[6] Li and Sailor (1995) and Sailor and Muñoz (1997) find in a sample of US states that temperature is the most significant weather factor explaining electricity and gas demand.

and in the basis (see Fama and French, 1987, p. 56). The effect of demand and supply shocks on spot and futures prices will depend on storage levels and how they are managed. Any demand or supply shock is easily offset when reservoirs are high – but when reservoirs are low, a demand or supply shock is more difficult to balance (and will be somewhat persistent, allowing spot and futures prices to increase). Haff et al. (2008) found in the UK natural gas market that inventory levels from the UK and EU are significant on short-run two and three month futures spreads (prompt and basis) as predicted by the theory of storage.

3. Data

In this section we compile the data sources in Table 1 and offer several graphical representations. Futures prices, traded volumes, and open interests are obtained directly from the ICE. There is a wide range of natural gas derivative contracts (forward, futures, and options) traded at the ICE. At the moment, the most important of the regulated contracts are monthly futures, especially the front month contract, the most liquid of all traded contracts. The numbers appearing in Figure 1(a) evidence this fact and it is especially true when looking at the trading volume, where first and second contracts closest to maturity represent more than the 80 per cent of total trades. To avoid low liquidity problems the study has been limited to the six-month contracts nearest to delivery.[7] In all these cases, the average monthly traded volume and open interest is above 100 and 6000 contracts, respectively. Average monthly time series of daily traded volume and open interest are shown in Figures 1(b) and 1(c), respectively. It can be appreciated that volumes and open positions steadily increase in the second half of the sample. Furthermore, from a casual visual inspection in this second half of the sample, it can be inferred that open interest values describe a seasonal pattern, taking peak and off-peak values in summer and winter respectively.

[7] Results and conclusions obtained for those monthly contracts with seven to twelve months to delivery are consistent and similar to those results and conclusions reported here for contracts with between one and six months to delivery. We have decided to omit these results to avoid liquidity criticism and reduce length.

Monthly time series are built by taking closing prices on the day prior to maturity of the front contract – avoiding in this way the 'last trading day' turbulences in the front contract. In the ICE, final futures settlement covers the difference between the last closing price of the futures contract and the *system average price* (SAP henceforth) in the 'delivery period' of all the calendar days of the month. Monthly SAP thus becomes the underlying spot reference on which expectations are projected and futures contracts priced. Finally, in order to catch seasonalities in futures prices and the risk premiums contained in them, we use weather and storage level variables (see Figures 2 and 3). The following section will add more comments on these variables. Figures 4 to 7 display all the risk premium time series described in the previous section.

High prices and risk premiums (see Figures 2 to 7) correspond to events mostly related with geopolitics: the dispute between Russia and Ukraine about the price of gas and transit combined with abnormally cold weather (3 March 2005, 22 November 2005, January 2009, February 2012) and the Libyan civil war (spring 2011). However, the most dramatic shortcoming and peak was during February and March 2006 when a cold spell was combined with a fire at the Rough natural gas storage facilities in the North Sea – preventing access to nearly 80% of total UK storage just as withdrawals from storage were about to begin (see Giulietti et al., 2011).

4. Results

Tables 2, 3 and 4 report the descriptive analysis of realized conventional risk premiums, rollover premiums, and the difference between both. All these tables contain two panels: one for realized returns defined in monetary units (pence) and another for log-returns. We use realized returns and log returns because both measures can be attractive for market agents. Alexander et al. (2013) argue that "...for assets with prices that can jump, log returns can be highly inaccurate proxies for percentage returns even when measured at the daily frequency". Consequently, we decided to report both returns measures in these tables. These compact tables report relevant information for the risk premium analysis: (1) average values for the whole period; (2) average values for each month of the year; (3) average values for the winter and summer seasons; and (4) volatility for winter and summer seasons.

Average values for the whole period are significantly different to zero, positive, and increase with the time to delivery. Day-ahead risk premiums value is 0.41 pence or 0.5 per cent. This is the first time this risk premium has been obtained and means that simultaneously selling day-ahead natural gas and buying it the following day in the spot market will report a 0.5% return of the total asset value every day. Conventional risk premiums vary between 0.99 and 6.14 pence or between 4.32 and 15.64 per cent for those contracts with between one and six months remaining to delivery. The rollover premiums are significatively higher between 0.24 and 3.52 pence or between 1.26 and 10.54 per cent for maturities of between three and six months (see Tables 3 and 4).[8]

Winter months contain the highest risk premiums in both cases (Tables 2 and 3). The significant and highest months are January and February. For example, finishing a futures trading strategy in January with positions engaged six months before would imply an average risk premium at delivery of 23.96 and 33.56 per cent for a single trade and rollover strategy, respectively. Differences are not significant in these cases but are significant in summer months, when rollover strategies are significatively higher but with lower values than in winter. To sum up, operating rollover strategies have a higher cost and this difference is significant in summer months (see median equality test in

[8] Agents will take strategic decisions in futures markets depending on the transaction costs involved and this is especially important in order to compare rollover strategies in the front contract versus strategies based on longer futures maturity contracts. The most important transaction cost in futures markets is the bid-ask spread. In order to compute the importance of the bid-ask spread involved in each futures strategy, we have taken bid and ask prices at hourly frequencies from October 23, 2014 until October 23, 2015 (2560 hourly observations). The bid-ask spread obtained for the 1, 2, 3, 4, and 5 months to maturity are 0.08, 0.10, 0.16, 0.23 and 0.41 pence; respectively. The relative bid-ask spreads obtained over the average between bid and ask prices are 0.17%, 0.23%, 0.36%, 0.50% and 0.89%; respectively. We can observe that transaction costs are neutral in our analysis as rollover 'n' times involves approximately the same costs as taking positions with futures contracts with 'n' months remaining to maturity (or 'n+1' months to delivery). Rolling over five times in front implies paying five times 0.17%, that is 0.85%; and the bid-ask spread in a five months to maturity contract is 0.89%. Transaction costs do not have an important role in the risk premium analysis conducted in this paper. Finally, extracted from ICE rules in May 2014, the total member trading fees for a contract would be £1.90 for NBP monthly contracts (about 0.003% of the underlying value).

Table 4, Panel A). Finally, winter volatility of both risk premiums is significantly higher than summer volatility when returns are taken into account (see Panel A in Tables 2 and 3).

To obtain further evidence on seasonal behavior in the UK natural gas market, *system average price* volatility and skewness are reported in Table 5. In each month or season, volatility, and skewness are computed considering the daily *system average price* contained during that period of time. In this way, we can build a monthly time-series of volatility and skewness statistics. Furthermore, these statistics are used in Equation 4 following Bessembinder and Lemmon (2002).[9] Volatility results in Table 5 are easy to interpret: volatility in winter months is higher. This result is statistically significant in raw returns reported in Panel A. Skewness coefficient differences between winter and summer months are not statistically significant.

Equation 4 is estimated for conventional risk premiums, rollover premiums, and the difference between them – and the results are reported in Tables 6, 7 and 8, respectively. These tables contain three panels (Panels A for the whole analyzed period, Panels B for the pre-crisis period, and Panels C for the crisis and post-crisis period). After the financial crisis starts, the demand for natural gas decreases and supply is then saturated due to an increase in shale gas production and the progressive expansion of LNG. Furthermore, the financial crisis depressurized the investment in commodities as financial assets.

Several insightful results are obtained:

(i) as we have shown previously, conventional and rollover risk premiums decrease in summer;

(ii) the standard deviation is significant at 1 or 5 per cent of significance level in most cases in the three tables. Consequently, risk premiums are closely related with

[9] In Equation 4, we use the standard deviation and the unstandardised skewness as these authors proposed.

uncertainty measured by the standard deviation of the SAP in the month in which the futures price is taken. That is, futures risk premiums are very sensitive to the spot market risk. This result was expected for rollover risk premiums, where this coefficient takes larger values in most cases (see Szymanowska et al. (2014));

(iii) unstandardised skewness is significant in Tables 6 and 7 in Panels A and B in most cases. We have not reported a graph of this statistics, but we can say that its mean value is not significant because its sign changes almost every month. Nevertheless, its sign is negative in all cases, and consequently risk premiums tend to respond in the opposite sign to the skewness;

(iv) futures market liquidity variables are measured by traded volume and open interest. Although in some cases these variables are significant in Tables 6 and 7, the most interesting result is reported in Table 8 where open interest is significant in most cases. At this point, we can conclude that differences between rollover and conventional risk premiums can be partially explained by liquidity in the futures market. It is interesting to note that the determination coefficient increases with maturity, achieving high values for this kind of study. These results imply that liquidity arguments are important for futures pricing;[10]

[10] In Figure 1 we observed that as the maturity increases, the liquidity variable values decreases. Nevertheless, we observe in Figure 1(c) how the two sub-periods (corresponding to Panels B and C in Tables 6, 7 and 8) have a different pattern. In the first sub-period the open interest is low and decreases with maturity. In the second sub-period, the open interest steadily increases and has a seasonal pattern: higher in summer and lower in winter. In Panel B in Table 8, it can be seen that the open interest coefficient is positive and increases with the time to maturity. Specifically, during this first sub-period, the open interest is relatively small and more than 50% is concentrated in the first and second contracts near to maturity. That is, a positive risk premium for liquidity preference in the rollover strategies exists. In the second sub-period (see Panel C at Table 8) the open interest coefficients are negative and decrease with maturity. During this sub-period the open interest steadily increases more than four times for all maturities. Furthermore, open interest during the summer months is about twice as high as the winter months for 3 to 6 months to maturity contracts. It is interesting to note that the reverse pattern is observed for first and second contracts near to maturity. That is, for these maturities, open interest during summer months is lower than winter months. A possible interpretation of these results is that if futures positions are taken when open interest is high (low) the difference between rollover and conventional risk premiums will decrease (increase). In Table 4, we see that differences between rollover and conventional risk premiums were positive and significant mostly in summer months (corresponding to strategies in futures started in winter) just when open interest is lower. Although a more thorough analysis of this issue is needed, there is some evidence for a liquidity risk component in the rollover risk premiums that is higher when liquidity in the futures contracts (except the front contract) is low. That is, the preference for the liquidity is paid.

(v) the proxy for the demand shocks measured by the accrued unexpected heating degrees days in a month is a very significant variable explaining risk premiums in Table 6 and 7. The UHDD variable has a negative and significant mean value, and consequently, we can understand that negative (positive) shocks in the demand increase (decrease) risk premiums. This result can be seen as counterintuitive – but we are dealing with risk premiums and not energy prices (where a clear positive relation exists).

(vi) The most interesting natural gas reservoir level influence on risk premiums is detected on the 1-day risk premium in Table 6. Reservoirs levels have a very important influence on futures prices due to a close relationship with convenience yield (see Haff et al. (2008)). Nevertheless, the influence of reservoir levels on risk premiums is not straightforward. The influence of reservoir level on the day-ahead risk premiums probably reflects the fact that reservoir management of any demand shock is a very specific risk for the spot market.

5. Conclusions

The seminal paper of Szymanowska et al. (2014) decomposes conventional risk premiums into two parts: the "spot component" and “term component". In our study, the spot component is named rollover risk premium and the term component is obtained as the difference between the rollover and conventional risk premiums. From this viewpoint, our results agree with the results of Szymanowska et al. (2014) as risk premiums in the UK natural gas futures are dominated by the “spot component” (rollover risk premiums exceed conventional risk premiums). Our study enriches this new approach to futures pricing in several ways. Seasonal patterns for mean and volatility are detected in rollover risk premiums, conventional risk premiums, and in the difference between them. Winter months feature higher and more volatile risk premiums. Furthermore, we have obtained determination coefficients between 21.68 and 59.08 per cent in our model explaining time-variation in both cases. Risk premiums respond to several risk factors specific to this market. As risk factors are able to explain time-varying realized risk premiums it can be understood that an important part of expected risk premiums are priced according to risk considerations. Specifically, seasonal dummies, the standard deviation and skewness of spot market price and unexpected weather shocks are very significant variables explaining risk premium time-variation. Further to this, storage levels are especially significant for explaining day ahead risk premiums. Finally, liquidity in the futures markets seems to be the most explicative variable explaining the difference between both risk premiums. This result implies that liquidity arguments are important for futures pricing.

Results in this paper are important for the design of most trading strategies in this futures market. Comparing rollover risk premiums with conventional risk premiums is an important preliminary issue before deciding which futures maturity to use – or if the higher liquidity of the front contract compensates a higher rollover risk premium.

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7. Tables

Table 1. Data sources

Variable	Description	Unit	Source
Futures prices	National Balancing Point (NBP) futures price for day-ahead and one to six months	pence/therm	Platts/Intercontinental Exchange (ICE)
System average price (SAP)	Average price of all gas traded via the on-the-day commodity market (OCM) mechanism for the gas day in UK	pence/therm	APX-ENDEX
Volume	Volume traded for the indicated trade day	pence/therm	Intercontinental Exchange (ICE)
Open interest	Open interest at the close of business on a trading day	pence/therm	Intercontinental Exchange (ICE)
Heating degree days (HDD)	HDD index: deviation of the daily accrued HDD for each month from the historical value of the HDD in the UK	Degrees Celsius	European Commission: Agri4Cast Data Portal
Storage	Working gas stocks of natural gas reservoirs for EU-28 and UK	Million cubic meters (mcm)	IEA and Howard Rogers from OIES

Note: All series from April 2000 to February 2015 with the exception of the HDD time series beginning in January 1974.

Table 2. Risk premiums

Taking monthly frequency data from April 2000 until February 2015 (179 observations) *ex post* risk premiums in 't' are computed as $F(t-j,t) - S(t)$ in Panel A and $100\times\log(F(t-j,t)/S(t))$ in Panel B for j = 1 day, 1 month, …, 6 months. For the day-ahead futures, the average value of the daily difference: $F(t-1\,day,t) - S(t)$ in Panel A and $100\times\log(F(t-1,t)/S(t))$ in Panel B is computed. Mean values and their p-value for the t-statistic mean zero hypotheses tests are reported between brackets. Winter season is defined by taking the following months: October, November, December, January, February and March. For summer season, the remaining months are taken. In 'Mean equality', 'Median equality' and 'Variance equality' rows, the t-statistic, the *Kruskal-Wallis* and the *Levene* tests statistics and their p values in brackets are reported.

	Panel A. Returns.						
	Time to maturity						
	1 day	1 months	2 month	3 months	4 months	5 months	6 months
Whole period	0.41 [0.00]	0.99 [0.02]	2.73[0.00]	4.24[0.00]	5.09[0.00]	5.62[0.00]	6.14[0.00]
January	0.68[0.11]	3.46[0.03]	7.93[0.03]	10.35[0.00]	12.09[0.01]	12.42[0.02]	12.34[0.01]
February	0.51[0.28]	1.54[0.37]	4.81[0.05]	8.95[0.02]	10.87[0.00]	12.33[0.02]	12.86[0.03]
March	0.49[0.19]	-2.21[0.20]	-0.01[1.00]	2.57[0.44]	5.07[0.17]	6.32[0.17]	8.13[0.19]
April	0.20[0.16]	1.15[0.25]	0.81[0.53]	2.45[0.35]	4.20[0.17]	4.45[0.17]	6.09[0.10]
May	0.17[0.25]	-0.14[0.88]	1.32[0.34]	1.11[0.52]	1.84[0.47]	3.19[0.27]	3.12[0.30]
June	0.19[0.19]	1.17[0.17]	1.35[0.30]	2.59[0.18]	2.04[0.37]	2.19[0.44]	3.25[0.29]
July	0.24[0.22]	0.24[0.82]	1.65[0.24]	0.88[0.61]	1.64[0.45]	0.84[0.73]	0.98[0.74]
August	-0.00[0.98]	1.09[0.14]	2.62[0.09]	3.40[0.03]	2.34[0.16]	2.90[0.17]	1.96[0.38]
September	0.28[0.21]	-1.41[0.32]	-0.14[0.93]	0.94[0.60]	1.70[0.36]	0.86[0.71]	1.46[0.61]
October	0.98[0.00]	3.02[0.10]	3.86[0.17]	4.66[0.11]	5.48[0.10]	6.30[0.07]	5.16[0.13]
November	0.94[0.09]	0.78[0.72]	3.83[0.25]	5.21[0.22]	5.34[0.12]	6.79[0.11]	7.52[0.10]
December	0.22[0.43]	3.04[0.13]	4.32[0.15]	7.18[0.13]	7.79[0.14]	7.98[0.08]	9.68[0.07]
Winter	0.64[0.00]	1.65[0.03]	4.17[0.00]	6.53[0.00]	7.80[0.00]	8.72[0.00]	9.29[0.00]
Summer	0.18[0.01]	0.34[0.40]	1.28[0.02]	1.89[0.01]	2.29[0.01]	2.38[0.02]	2.81[0.02]
Mean equality	2.74[0.01]	1.56[0.12]	2.23[0.02]	2.89[0.00]	3.11[0.00]	3.16[0.00]	2.89[0.00]
Median Equality	4.57[0.03]	3.34[0.07]	2.38[0.12]	4.03[0.04]	5.32[0.02]	6.09[0.01]	4.48[0.03]
Winter Volatility	1.46	6.90	11.07	13.35	14.44	16.04	17.79
Summer Volatility	0.63	3.83	5.14	6.85	8.07	9.39	10.58
Variance Equality	16.81[0.00]	7.47[0.01]	23.77[0.00]	17.30[0.00]	13.19[0.00]	9.95[0.00]	8.28[0.00]

	Panel B. Log-returns						
	Time to maturity						
	1 day	1 months	2 month	3 months	4 months	5 months	6 months
Whole period	0.50[0.00]	4.32[0.00]	8.69[0.00]	11.86[0.00]	13.69[0.00]	14.66[0.00]	15.64[0.00]
January	0.59[0.09]	9.07[0.01]	17.74[0.01]	23.36[0.00]	24.73[0.01]	23.57[0.01]	23.96[0.01]
February	0.31[0.08]	4.73[0.22]	14.15[0.02]	22.14[0.01]	26.81[0.00]	27.81[0.01]	26.90[0.02]
March	0.51[0.05]	-0.74[0.77]	4.69[0.48]	12.77[0.10]	18.10[0.04]	21.71[0.04]	23.55[0.06]
April	0.42[0.03]	4.26[0.15]	4.62[0.21]	9.11[0.20]	15.09[0.07]	16.70[0.07]	20.62[0.04]
May	0.34[0.08]	-1.21[0.75]	3.47[0.40]	3.77[0.48]	6.14 0.39]	10.83[0.18]	11.74[0.16]
June	0.32[0.13]	5.71[0.07]	3.92[0.38]	8.14[0.13]	7.50[0.24]	8.14[0.29]	12.22[0.14]
July	-0.23[0.70]	2.56[0.57]	8.69[0.12]	3.74[0.59]	6.46[0.36]	5.24[0.53]	5.71[0.54]
August	0.48[0 .24]	5.77[0.07]	8.96[0.06]	12.41[0.03]	6.73[0.25]	7.99[0.20]	6.74[0.36]
September	0.52[0.11]	-2.17[0.60]	2.88[0.59]	4.35[0.51]	7.89[0.26]	2.82[0.74]	5.63[0.53]
October	1.80[0.01]	12.03[0.04]	12.58[0.13]	15.88[0.07]	17.01[0.07]	19.68[0.05]	15.05[0.15]
November	0.68[0.03]	4.53[0.27]	9.90[0.10]	10.46[0.14]	12.10[0.06]	14.18[0.07]	15.89[0.05]
December	0.24[0.34]	6.93[0.05]	11.77[0.07]	15.31[0.08]	14.74[0.11]	16.10[0.06]	18.07[0.06]
Winter	0.69[0.00]	6.17[0.00]	11.88[0.00]	16.70[0.00]	18.92[0.00]	20.50[0.00]	20.54[0.00]
Summer	0.31[0.03]	2.47[0.09]	5.45[0.00]	6.92[0.00]	8.28[0.00]	8.55[0.01]	10.44[0.00]
Mean equality	1.95[0.05]	1.74[0.08]	2.07[0.04]	2.59[0.01]	2.56 [0.01]	2.58[0.01]	2.00[0.04]
Median Equality	2.88[0.09]	2.49[0.11]	2.25[0.13]	3.39[0.06]	4.38[0.03]	5.35[0.02]	3.04[0.08]
Winter Volatility	13.28	14.73	23.72	27.68	30.00	32.25	35.31
Summer Volatility	13.01	13.63	17.04	22.13	24.64	28.43	30.60
Variance Equality	1.61[0.21]	0.82[0.36]	8.93[0.00]	3.06[0.08]	1.14[0.28]	0.07[0.78]	0.00[0.97]

Table 3. Rollover premiums

In Panel A, rollover premiums are computed as $[F(t-1,t)-S(t)]+\sum_{k=1}^{j-1}\left[F(t-(k+1),t-(k-1))-F(t-k,t-(k-1))\right]$ for j = 3 months, …, 6 months. In Panel B, rollover premiums are computed as $100\times\left[\ln(F(t-1,t)/S(t))+\sum_{k=1}^{j-1}\ln(F(t-(k+1),t-(k-1))/F(t-k,t-(k-1)))\right]$ for j = 3 months, …, 6 months. Other comments are identical to those of Table 2.

	Panel A. Returns.				Panel B. Log-returns			
	Time to maturity				Time to maturity			
	3 months	4 months	5 months	6 months	3 months	4 months	5 months	6 months
Whole period	4.48[0.00]	6.18[0.00]	7.91[0.00]	9.66[0.00]	13.12[0.00]	17.44[0.00]	21.69[0.00]	26.17[0.00]
January	9.21[0.01]	12.26[0.01]	13.10[0.03]	14.37[0.02]	22.58[0.01]	27.95[0.01]	28.51[0.03]	33.56[0.01]
February	9.27[0.02]	10.56[0.01]	13.61[0.01]	14.45[0.02]	22.82[0.01]	27.65[0.01]	33.03[0.01]	33.58[0.02]
March	3.30[0.33]	7.45[0.07]	9.04[0.10]	12.11[0.09]	14.38[0.08]	22.52[0.02]	28.08[0.03]	33.46[0.03]
April	3.01[0.35]	6.32[0.09]	10.47[0.03]	12.06[0.03]	10.05[0.23]	19.75[0.05]	27.88[0.02]	33.44[0.02]
May	0.99[0.58]	3.18[0.36]	6.49[0.11]	10.65[0.04]	3.83[0.49]	9.25[0.31]	18.95[0.07]	27.09[0.02]
June	2.99[0.13]	2.66[0.23]	4.85[0.20]	8.16[0.07]	9.59[0.07]	9.95[0.11]	15.37[0.12]	25.07[0.03]
July	1.84[0.35]	3.41[0.16]	3.07[0.27]	5.27[0.22]	6.89[0.34]	11.72[0.12]	12.08[0.19]	17.50[0.16]
August	4.03[0.02]	4.22[0.05]	5.69[0.02]	5.35[0.05]	15.09[0.02]	13.29[0.05]	16.87[0.02]	17.23[0.04]
September	1.39[0.42]	2.80[0.14]	2.99[0.22]	4.75[0.09]	6.07[0.31]	12.20[0.08]	10.40[0.24]	16.35[0.08]
October	5.14[0.11]	6.67[0.10]	8.08[0.05]	8.27[0.07]	17.63[0.06]	20.82[0.05]	26.95[0.02]	25.15[0.06]
November	4.67[0.25]	5.94[0.17]	7.47[0.16]	8.88[0.09]	10.45[0.18]	15.51[0.07]	18.70[0.07]	24.83[0.02]
December	7.37[0.09]	8.21[0.12]	9.48[0.09]	11.02[0.08]	17.14[0.06]	17.69[0.11]	22.75[0.05]	25.94[0.04]
Winter	6.53[0.00]	8.53[0.00]	10.14[0.00]	11.51[0.00]	17.54[0.00]	22.02[0.00]	26.31[0.00]	29.37[0.00]
Summer	2.38[0.00]	3.76[0.00]	5.56[0.00]	7.71[0.00]	8.61[0.00]	12.69[0.00]	16.85[0.00]	22.78[0.00]
Mean equality	2.56[0.01]	2.44[0.01]	1.93[0.06]	1.39[0.16]	2.24[0.03]	1.98[0.04]	1.69[0.09]	1.04[0.30]
Median Equality	2.71[0.09]	2.77[0.09]	1.83[0.18]	0.57[0.44]	2.36[0.12]	1.69[0.09]	2.07[0.15]	0.75[0.38]
Winter Volatility	13.19	15.49	18.40	20.61	29.16	34.60	40.24	45.13
Summer Volatility	7.47	9.45	12.14	14.41	23.10	27.23	32.98	37.82
Variance Equality	15.31[0.00]	11.32[0.00]	7.19[0.00]	6.18[0.01]	3.94[0.04]	1.56[0.21]	1.07[0.30]	0.66[0.41]

Table 4. Liquidity premiums

Liquidity premiums are computed as the difference between the rollover and the risk premiums for j = 3 months, …, 6 months obtained in Tables 2 and 3. Other comments are identical to those of Table 2 and Table 3.

	Panel A. Returns.				Panel B. Log-returns			
	Time to maturity				Time to maturity			
	3 months	4 months	5 months	6 months	3 months	4 months	5 months	6 months
Whole period	0.24[0.18]	1.09[0.00]	2.28[0.00]	3.52[0.00]	1.26[0.00]	3.75[0.00]	7.03[0.00]	10.54[0.00]
January	-1.14[0.25]	0.17[0.82]	0.67[0.71]	2.03[0.25]	-0.79[0.68]	3.22[0.14]	4.93[0.29]	9.60[0.05]
February	0.33[0.15]	-0.31[0.73]	1.28[0.15]	1.59[0.41]	0.67[0.29]	0.85[0.69]	5.22[0.07]	6.68[0.19]
March	-0.12[0.80]	1.35[0.36]	3.30[0.04]	7.53[0.01]	0.05[0.96]	3.12[0.32]	8.12[0.04]	15.35[0.00]
April	0.56[0.56]	2.12[0.05]	6.02[0.02]	5.97[0.02]	0.95[0.68]	4.66[0.10]	11.19[0.00]	12.82[0.02]
May	-0.12[0.80]	1.35[0.36]	3.30[0.04]	7.53[0.01]	0.05[0.96]	3.12[0.32]	8.12[0.04]	15.35[0.00]
June	0.95[0.09]	1.77[0.01]	2.23[0.02]	4.29[0.03]	3.15[0.04]	5.26[0.01]	6.84[0.00]	11.80[0.01]
July	0.95[0.09]	1.77[0.01]	2.23[0.02]	4.29[0.03]	3.15[0.04]	5.26[0.01]	6.84[0.00]	11.80[0.01]
August	0.63[0.06]	1.88[0.02]	2.79[0.00]	3.39[0.01]	2.68[0.03]	6.57[0.00]	8.87[0.00]	10.49[0.00]
September	0.45[0.25]	1.10[0.10]	2.14[0.03]	3.30[0.01]	1.72[0.14]	4.30[0.02]	7.58[0.00]	10.71[0.00]
October	0.48[0.59]	1.19[0.32]	1.78[0.26]	3.11[0.10]	1.74[0.35]	3.81[0.14]	7.27[0.04]	10.11[0.02]
November	-0.54[0.50]	0.60[0.60]	0.69[0.67]	1.36[0.53]	-0.01[1.00]	3.40[0.17]	4.52[0.22]	8.93[0.05]
December	0.19[0.76]	0.42[0.77]	1.51[0.26]	1.34[0.43]	1.83[0.15]	2.96[0.38]	6.64[0.06]	7.87[0.07]
Winter	-0.00[1.00]	0.72[0.09]	1.43[0.01]	2.21[0.00]	0.84[0.17]	3.10[0.00]	5.82[0.00]	8.84[0.00]
Summer	0.49[0.02]	1.47[0.00]	3.18[0.00]	4.90[0.00]	1.70[0.00]	4.42[0.00]	8.30[0.00]	12.34[0.00]
Mean equality	-1.37[0.17]	-1.36[0.18]	-2.18[0.03]	-2.59[0.01]	-1.06[0.29]	-1.03[0.31]	-1.41[0.16]	-1.55[0.12]
Median Equality	3.98[0.04]	5.32[0.02]	9.81[0.00]	10.60[0.00]	2.30[0.13]	2.88[0.09]	4.74[0.03]	3.07[0.08]
Winter Volatility	2.71	4.03	5.41	6.79	5.74	9.18	12.87	15.91
Summer Volatility	1.94	3.20	5.18	6.84	5.05	7.75	10.03	13.70
Variance Equality	3.98[0.04]	2.70[0.10]	0.82[0.36]	0.02[0.92]	1.87[0.17]	2.56[0.11]	4.32[0.04]	1.40[0.24]

Table 5. Volatility and skewness of system average price

The standard deviation and the skewness coefficients for the daily system average price are computed within each month in the sample using returns and log-returns in Panel A and B, respectively. Other comments are identical to those of Table 2.

	Panel A. Returns		Panel B. Log-returns	
	Volatility	Skewness	Volatility	Skewness
Whole period	3.00 [0.00]	0.11 [0.05]	12.73 [0.00]	-0.32 [0.00]
January	3.28 [0.00]	0.48 [0.14]	11.10 [0.00]	0.28 [0.33]
February	3.24 [0.00]	-0.29 [0.05]	12.72 [0.00]	0.61 [0.00]
March	5.14 [0.03]	0.00 [0.99]	13.43 [0.00]	0.07 [0.78]
April	2.08 [0.00]	0.36 [0.16]	9.07 [0.00]	-0.05 [0.80]
May	2.31 [0.00]	0.10 [0.41]	10.65 [0.00]	-0.43 [0.05]
June	2.22 [0.00]	0.13 [0.47]	9.22 [0.00]	-0.32 [0.23]
July	2.22 [0.00]	-0.07 [0.49]	12.15 [0.00]	-0.42 [0.06]
August	2.10 [0.00]	-0.20 [0.24]	11.18 [0.00]	-0.45 [0.03]
September	3.00 [0.00]	0.18 [0.42]	15.44 [0.00]	-0.64 [0.01]
October	3.87 [0.00]	0.34 [0.08]	22.18 [0.00]	-1.29 [0.00]
November	3.26 [0.00]	0.21 [0.22]	13.52 [0.00]	-0.77 [0.00]
December	3.47 [0.00]	0.09 [0.70]	12.14 [0.00]	-0.43 [0.19]
Winter	3.70 [0.00]	0.14 [0.12]	14.19 [0.00]	-0.26 [0.03]
Summer	2.32 [0.00]	0.08 [0.25]	11.29 [0.00]	-0.39 [0.00]
Mean Equality	3.21[0.00]	0.48[0.62]	1.90[0.05]	0.87[0.38]
Median Equality	3.18[0.00]	0.42[0.66]	1.03[0.31]	0.88[0.35]

Table 6. Regression of risk premiums on explicative variables

This table reports the estimation results of the following regression

$$F(t-j,t)-S(t)=aWinter+bSummer+cSD(t-j)+dSkew(t-j)+eVol(t-j)+fOI(t-j)+gUHDD(t-j)+hEU(t-j)+iUK(t-j)+\varepsilon(t-j,t)$$

for j = 1 *day*, 1, 2, 3, 4, 5 and 6 months to delivery. Winter and summer are dummies for the seasons. *SD* and *Skew* refer to the standard deviation and unstandardized skewness within each month of the daily system average price. *Vol* and *OI* refer to the monthly average of the daily traded volume and open interest of each futures contract. *UHDD* represents the difference between the historical value and the observed daily accrued heating degree day for each month within the year for the United Kingdom. *EU* and *UK* refer to the natural gas reservoirs levels in the European Union and the United Kingdom, respectively. Significance of the coefficients at the 1%, 5% and 10% levels are indicated with one (*), two (**) and three (***) asterisks, respectively; based on the *t*-statistics computed with the Newey-West consistent estimators. For the day-ahead futures the dependent variable is computed in each month as the average value of $F(t-1\,day,t)-S(t)$.

Time to delivery	*Winter*	*Summer*	*SD*	$Skew\times10^4$	$Vol\times10^3$	$OI\times10^4$	$UHDD\times10^2$	$EU\times10^4$	$UK\times10^3$	R^2(%)
Panel A. Whole period (April 2000- February 2015)										
1 day	-0.37	***-0.42	*0.21	*-0.35			-0.14	**-0.21	*0.34	53.10
1 month	***-3.63	**-3.99	*0.66	*-1.78	-0.01	-0.12	**-3.48	0.19	0.22	25.05
2 months	**-7.09	*-9.09	*1.20	*-3.48	0.26	-0.01	*-6.81	1.11	-0.51	31.31
3 months	**-5.76	*-9.88	*1.35	*-4.23	*4.39	-1.70	*-8.30	1.21	-0.54	31.15
4 months	-2.66	**-8.53	*1.36	*-5.41	**7.87	-1.61	*-7.84	1.23	-1.01	26.83
5 months	-0.74	**-8.78	*1.36	*-4.44	***13.44	-0.94	*-9.42	1.50	-1.90	25.53
6 months	3.65	-6.54	*1.35	**-3.79	9.07	1.29	*-9.65	0.56	-1.28	21.68
Panel B. Pre-crisis period (April 2000- August 2008)										
1 day	-0.03	-0.30	*0.22	*-0.45			0.15	-0.10	0.14	57.37
1 month	-1.34	-1.32	*0.64	**-1.73	-0.77	-3.77	**-4.88	0.64	-0.19	34.29
2 months	**-9.40	**-11.01	*1.33	*-4.02	**-8.43	3.35	*-7.92	**2.44	-2.19	42.13
3 months	-2.15	-6.86	*1.12	**-3.64	***-18.35	-8.07	*-11.51	**2.95	***-3.00	37.96
4 months	3.76	-1.51	*0.88	*-3.67	-25.39	-13.30	*-10.75	2.48	-3.07	33.21
5 months	5.53	-2.05	*0.87	***-1.84	-25.44	-10.10	*-13.26	1.41	-2.22	31.15
6 months	**10.62	3.16	**0.84	-1.55	-11.81	-0.20	*-13.61	0.57	-2.16	28.13
Panel C. Crisis and Post-crisis period (September 2008-February 2015)										
1 day	0.12	0.14	*0.07	*-6.16			-0.124	**-0.21	**0.27	59.08
1 month	1.86	-0.15	**0.36	*-19.8	-0.24	0.21	-2.287	-1.00	1.56	22.89
2 months	5.39	0.74	*0.96	4.86	1.81	**-4.53	-3.774	-2.81	**5.43	30.10
3 months	9.43	4.57	*1.13	-7.28	*7.04	*-9.78	***-4.461	-3.39	*7.41	47.10
4 months	**10.17	5.51	*1.35	-27.1	*13.31	*-10.8	-3.843	-3.81	**8.08	48.91
5 months	8.85	5.56	**1.33	***-43.4	*23.78	*-11.1	***-6.252	-1.39	3.75	46.22
6 months	**14.12	6.92	**1.43	-36.3	22.98	**-8.29	-4.771	-3.19	5.28	32.91

Table 7. Regression of rollover premiums on explicative variables

This table shows the estimation results of the regression

$$RO(t-j,t) = aWinter + bSummer + cSD(t-j) + dSkew(t-j) + eVol(t-j) + fOI(t-j) + gUHDD(t-j) + hEU(t-j) + iUK(t-j) + \varepsilon(t-j,t)$$

for j = 3, 4, 5 and 6 months to maturity. Realized rollover premiums from $t-j$ until t are computed as follows

$$RO(t-j,t) = (F(t-1,t) - S(t)) + \sum_{k=2}^{j}(F(t-k-1,t-k) - F(t-k,t-k))$$

for j = 3, 4, 5 and 6 months. Other comments are identical to those of Table 3.

Time to delivery	*Winter*	*Summer*	*SD*	$Skew\times10^4$	$Vol\times10^3$	$OI\times10^4$	$UHDD\times10^2$	$EU\times10^4$	$UK\times10^3$	R^2(%)
Panel A. Whole period (April 2000- February 2015)										
3 months	***-6.34	**-9.94	*1.42	*-4.48	*4.59	**-2.01	*-8.493	1.23	-0.44	32.54
4 months	-3.08	***-8.28	*1.52	*-5.48	**7.44	**-2.16	*-8.619	1.14	-0.59	26.37
5 months	-1.13	***-7.94	*1.87	*-5.92	***16.2	-2.04	*-11.587	1.03	-1.06	28.58
6 months	2.99	-5.94	*2.10	*-6.79	19.44	-0.60	*-11.168	0.10	-0.32	25.29
Panel B. Pre-crisis period (April 2000- August 2008)										
3 months	-4.74	***-9.25	*1.25	*-3.95	-16.98	-3.15	*-11.30	*2.83	-2.65	38.17
4 months	2.53	-3.03	*1.08	*-3.80	-26.42	-7.04	*-11.27	2.34	-2.81	32.24
5 months	5.84	-2.06	*1.56	*-3.68	-38.44	2.17	*-17.10	0.57	-1.58	38.21
6 months	**11.78	3.33	*1.83	*-5.28	-20.46	2.14	*-16.48	-1.15	-0.59	35.63
Panel C. Crisis and Post-crisis period (September 2008-February 2015)										
3 months	***11.30	7.25	*1.10	-11.40	*7.30	*-10.8	**-4.967	***-3.97	*8.25	50.08
4 months	**13.93	10.62	*1.34	-30.70	*13.57	*-13.6	-4.238	***-5.25	*10.76	49.60
5 months	11.82	11.14	**1.44	***-45.20	*28.25	*-15.4	***-6.621	-2.84	6.88	45.57
6 months	**16.58	13.31	**1.53	-50.10	**35.35	*-14.6	-4.932	-4.17	***8.19	35.32

Table 8. Regression of the difference between the rollover and risk premiums on explicative variables

This table shows the estimation results of the following regression

$$RO(t-j,t)-\left[F(t-j,t)-S(t)\right]=$$

$$a\text{Winter}+bSummer+cSD(t-j)+dSkew(t-j)+eVol(t-j)+fOI(t-j)+gUHDD(t-j)+hEU(t-j)+iUK(t-j)+\varepsilon(t-j,t)$$

for j = 3, 4, 5 and 6 months to maturity. Other comments are identical to those of Table 3 and 4.

Panel A. Whole period (April 2000- February 2015)

Time to delivery	*Winter*	*Summer*	*SD*	$Skew\times10^4$	$Vol\times10^3$	$OI\times10^4$	$UHDD\times10^2$	$EU\times10^4$	$UK\times10^3$	R^2(%)
3 months	-0.58	-0.06	0.07	-0.26	0.20	-0.31	-0.19	0.02	0.11	3.08
4 months	-0.41	0.25	***0.15	-0.07	-0.43	***-0.55	-0.77	-0.08	0.42	8.35
5 months	-0.38	0.83	**0.51	**-1.47	2.76	**-1.10	**-2.16	-0.46	0.84	20.46
6 months	-0.66	0.60	*0.75	*-3.00	*10.37	*-1.89	-1.52	-0.46	0.96	23.04
Panel B. Pre-crisis period (April 2000- August 2008)										
3 months	-2.60	-2.39	**0.13	-0.31	1.38	***4.92	0.21	-0.13	3.45	8.8
4 months	-1.23	-1.51	*0.21	-0.13	-1.03	**6.30	-0.52	-0.14	2.61	12.04
5 months	0.31	-0.01	**0.68	**-1.84	-13.01	*12.30	*-3.84	-0.85	6.44	37.78
6 months	1.16	0.17	*0.99	*-3.73	-8.65	*22.10	***-2.88	**-1.72	***1.56	40.23
Panel C. Crisis and Post-crisis period (September 2008-February 2015)										
3 months	1.88	2.69	-0.03	-4.15	0.26	***-1.06	-0.51	-0.57	0.84	10.20
4 months	3.77	***5.11	-0.01	-3.57	0.26	**-2.83	-0.39	-1.44	***2.68	18.62
5 months	2.97	5.58	0.11	-1.83	***4.47	*-4.30	-0.37	-1.46	***3.13	20.85
6 months	2.46	6.39	0.09	**-13.8	*12.37	*-6.31	-0.16	-0.98	2.91	27.91

Figure 1. Monthly average traded volume and open interest

These figures show the monthly average traded volume and open interest. M1 to M12 are used to indicate the contracts with 1 month to 12 months left until maturity of monthly futures contracts.

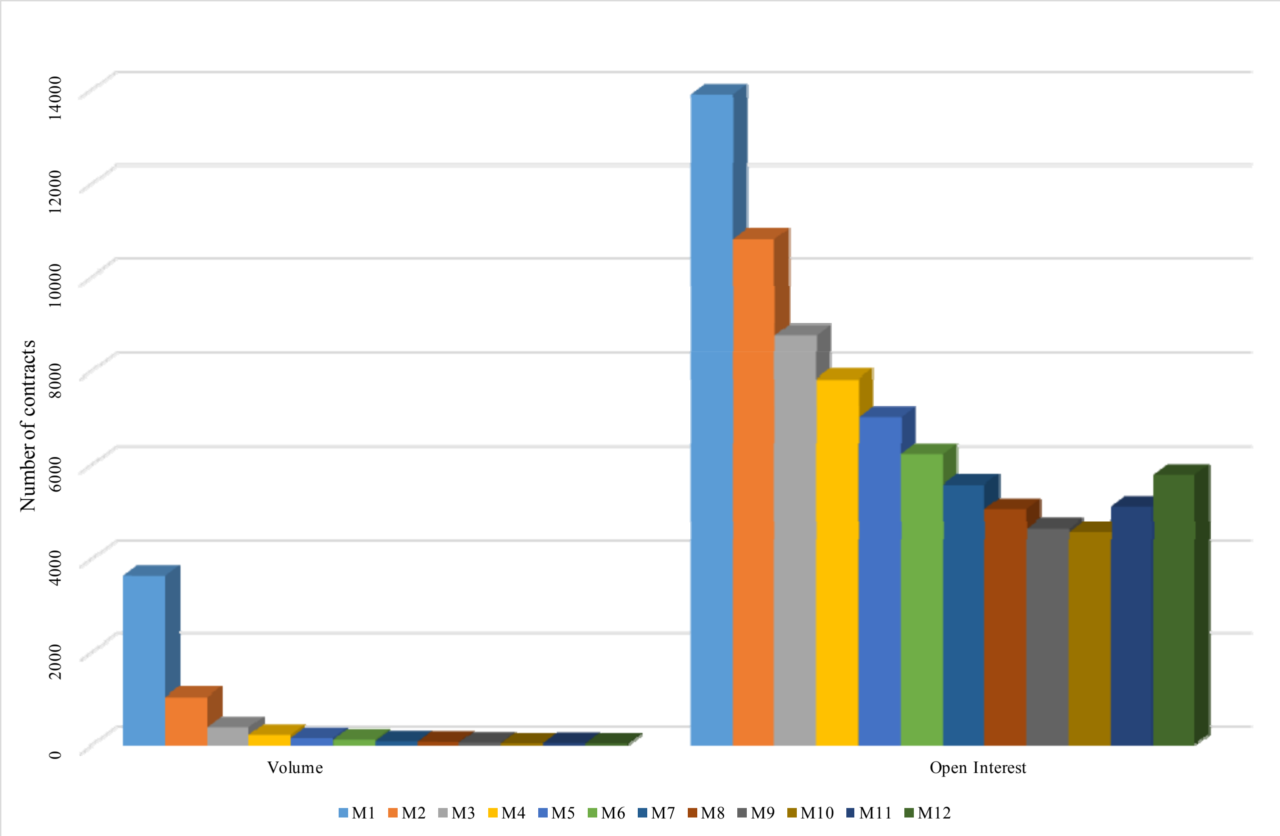


Figure 1(a). These figures show the total average monthly traded volume (left) and total average monthly open interest (right).

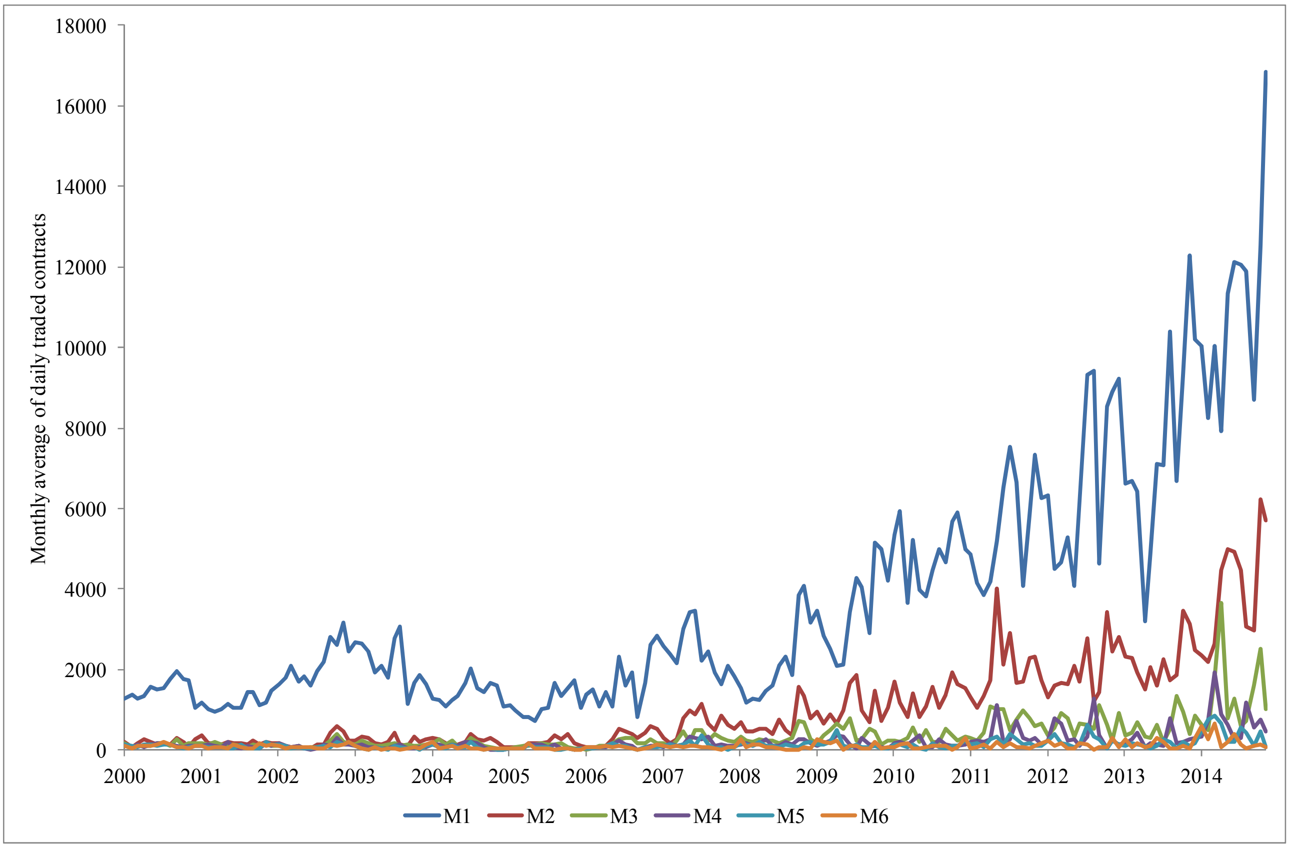


Figure 1(b). This figure shows the monthly average traded volume time series for contracts with 1 month to 6 months left until maturity.

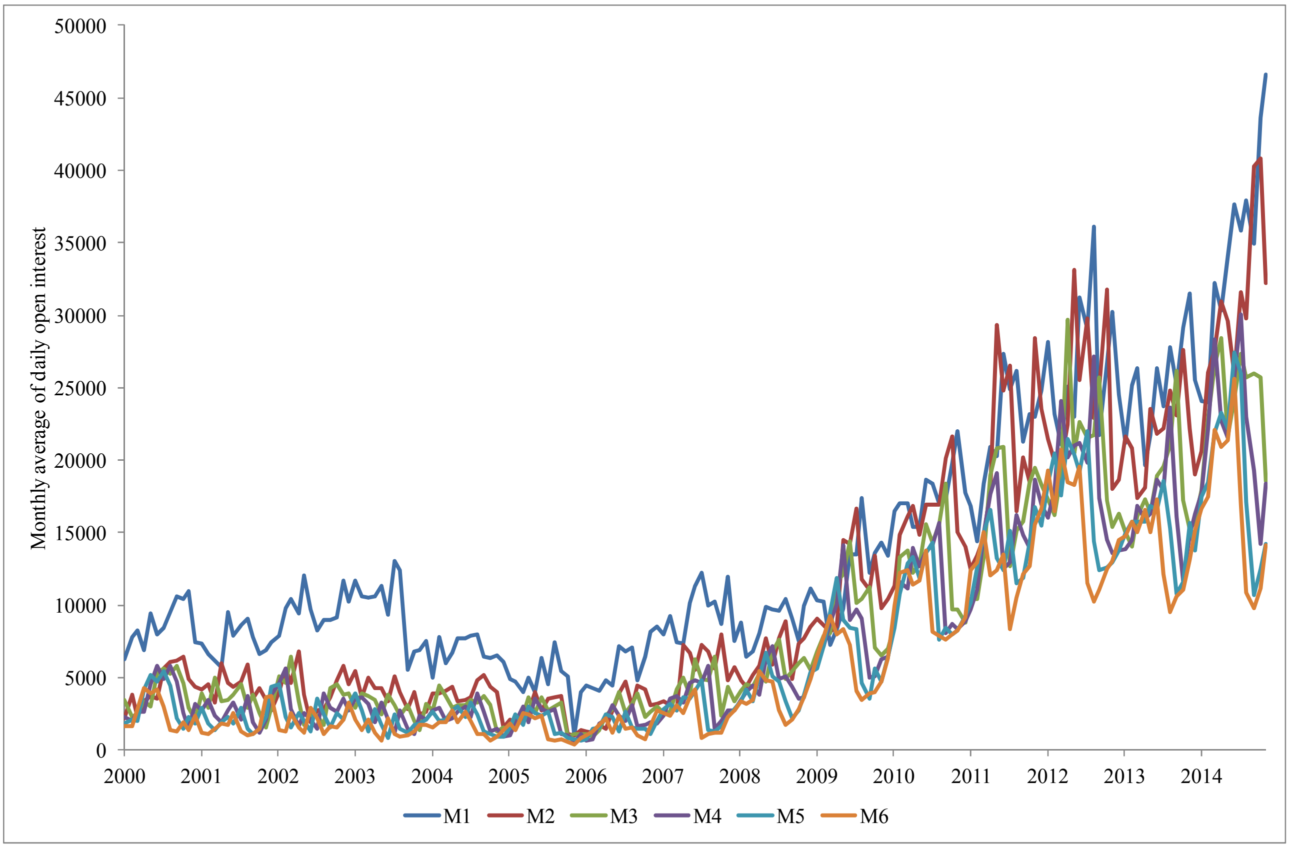


Figure 1(c). This figure shows the monthly average open interest time series for contracts with 1 month to 6 months left until maturity.

Figure 2. Heating Degree Days in the United Kingdom

This figure shows the monthly heating degree days in the dashed line (-----) and its historical average value for each month in the continuous line (──). Historical average value is computed using the heating degree days since 1974 until the previous to the current year.

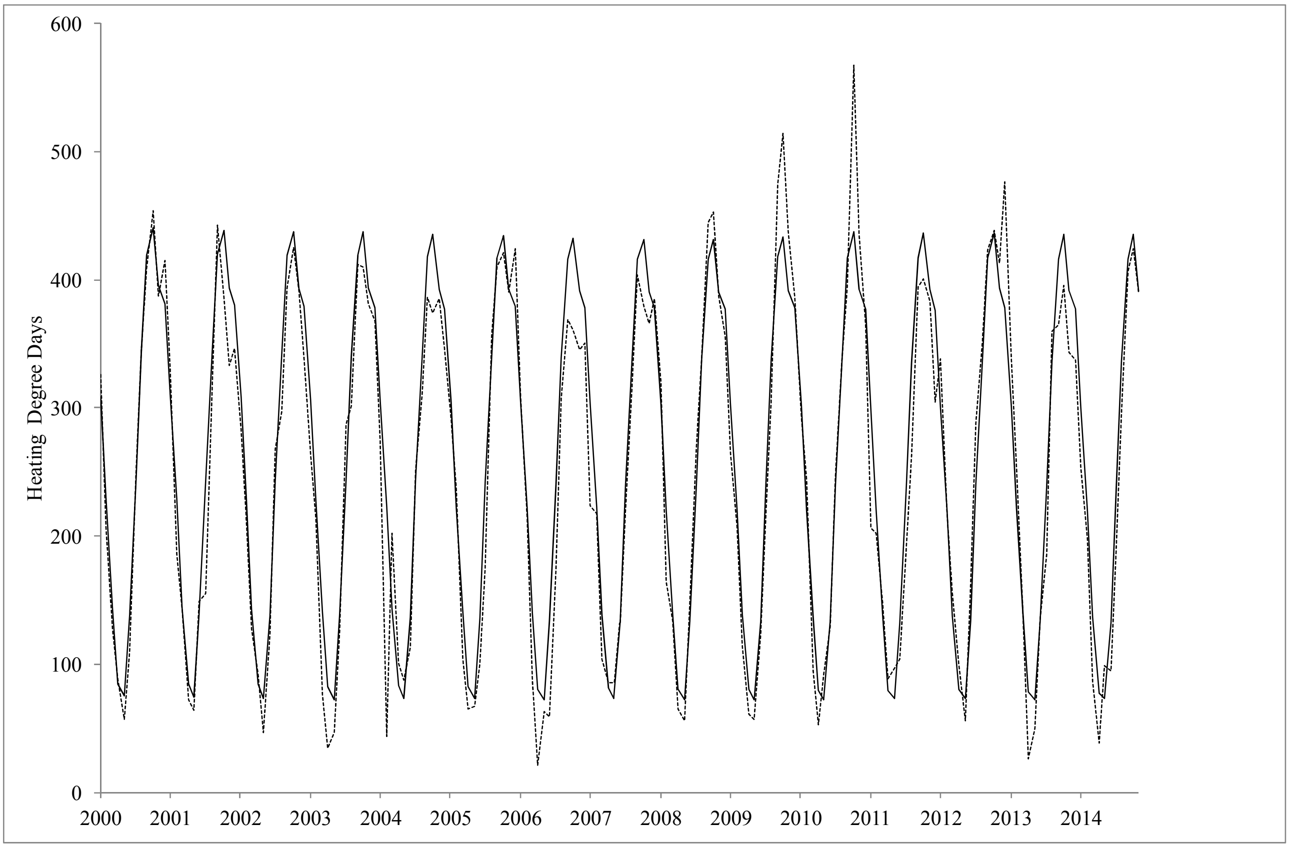


Figure 3. Natural gas storage levels

This figure reports the monthly natural gas storage levels in European countries in the continuous line (──) and in the United Kingdom in the dashed line (-----).

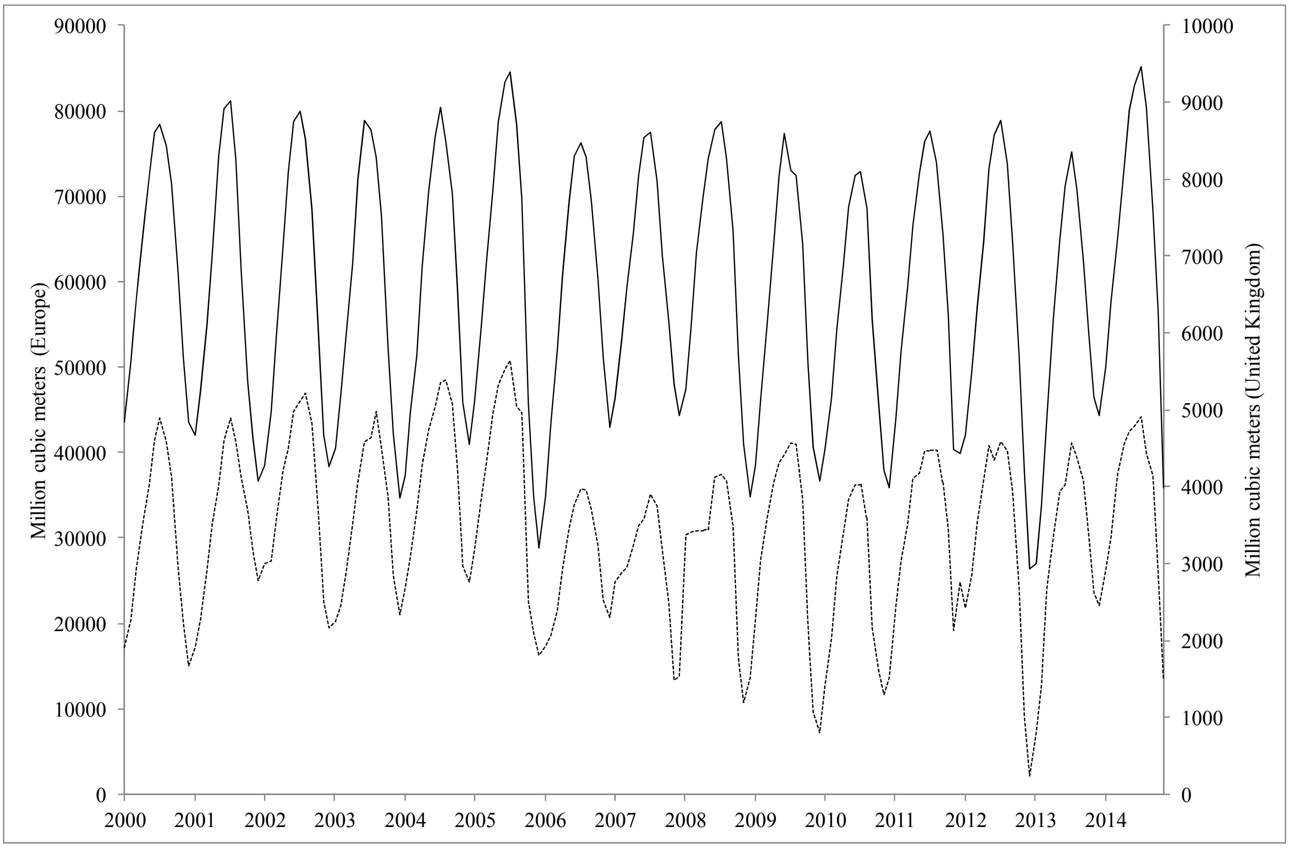


Figure 4

Day-ahead monthly average price (------), Monthly system average price (——) and the monthly average risk premium (·······) contained in day-ahead prices computed as the difference between the previous two.

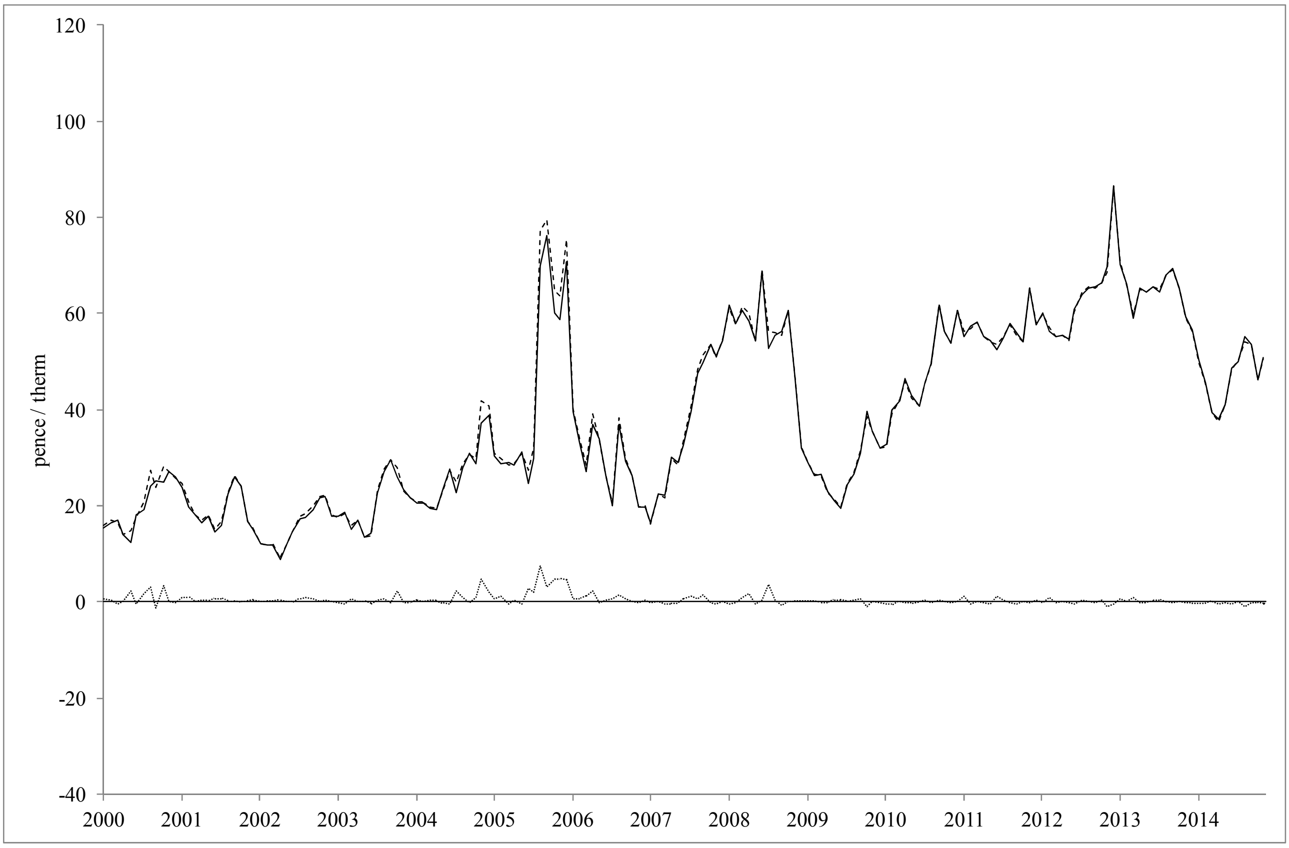


Figure 5

Futures front contract price ($F(t-1,t)$) on the day prior to maturity (------); monthly system average Price ($S(t)$) (——); and the *ex post* observed risk premium in 't' (·······) computed as $F(t-1,t) - S(t)$.

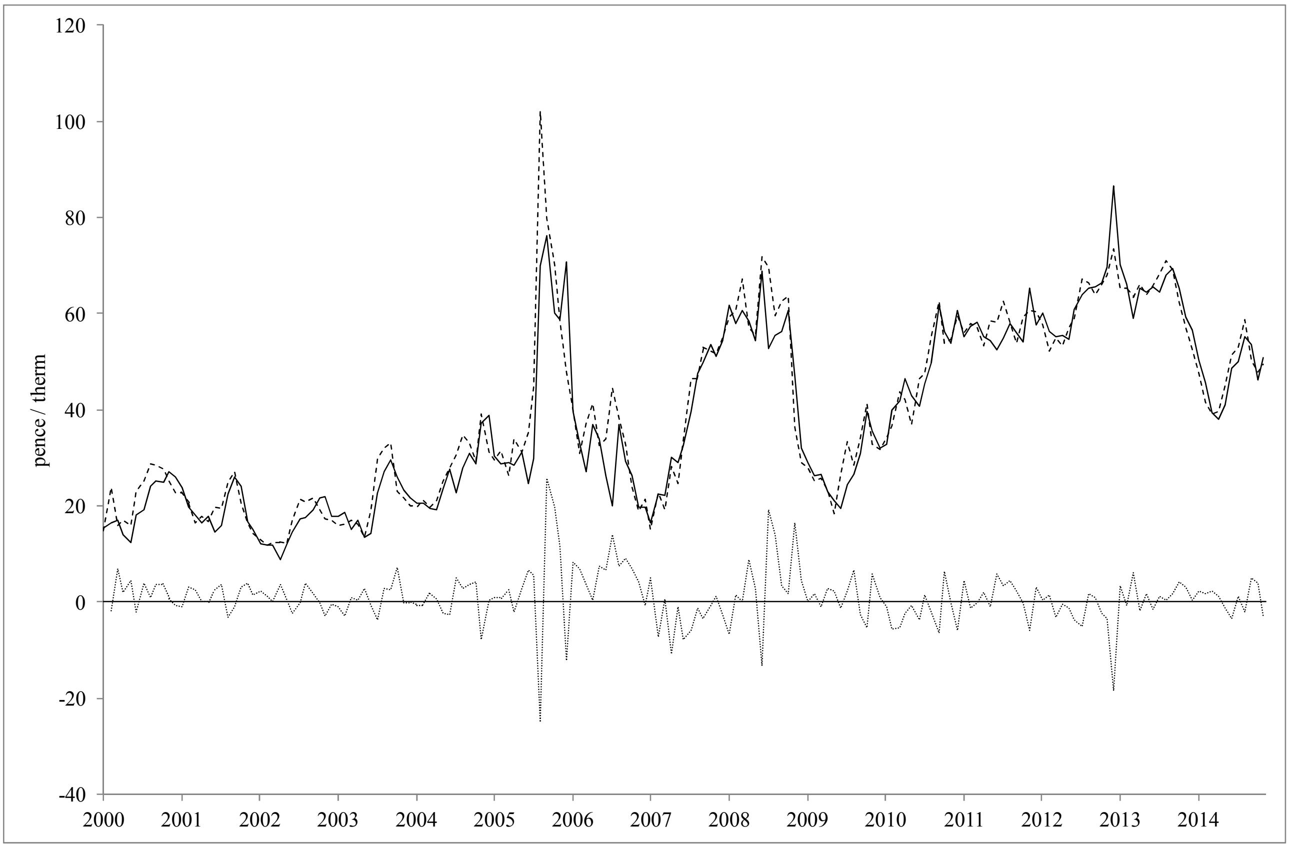


Figure 6

Second to maturity futures contract price ($F(t\text{–}2,t)$) (------), monthly system average price ($S(t)$) (——), and the *ex post* observed risk premium in 't' (·······) computed as $F(t\text{–}2,t) - S(t)$.

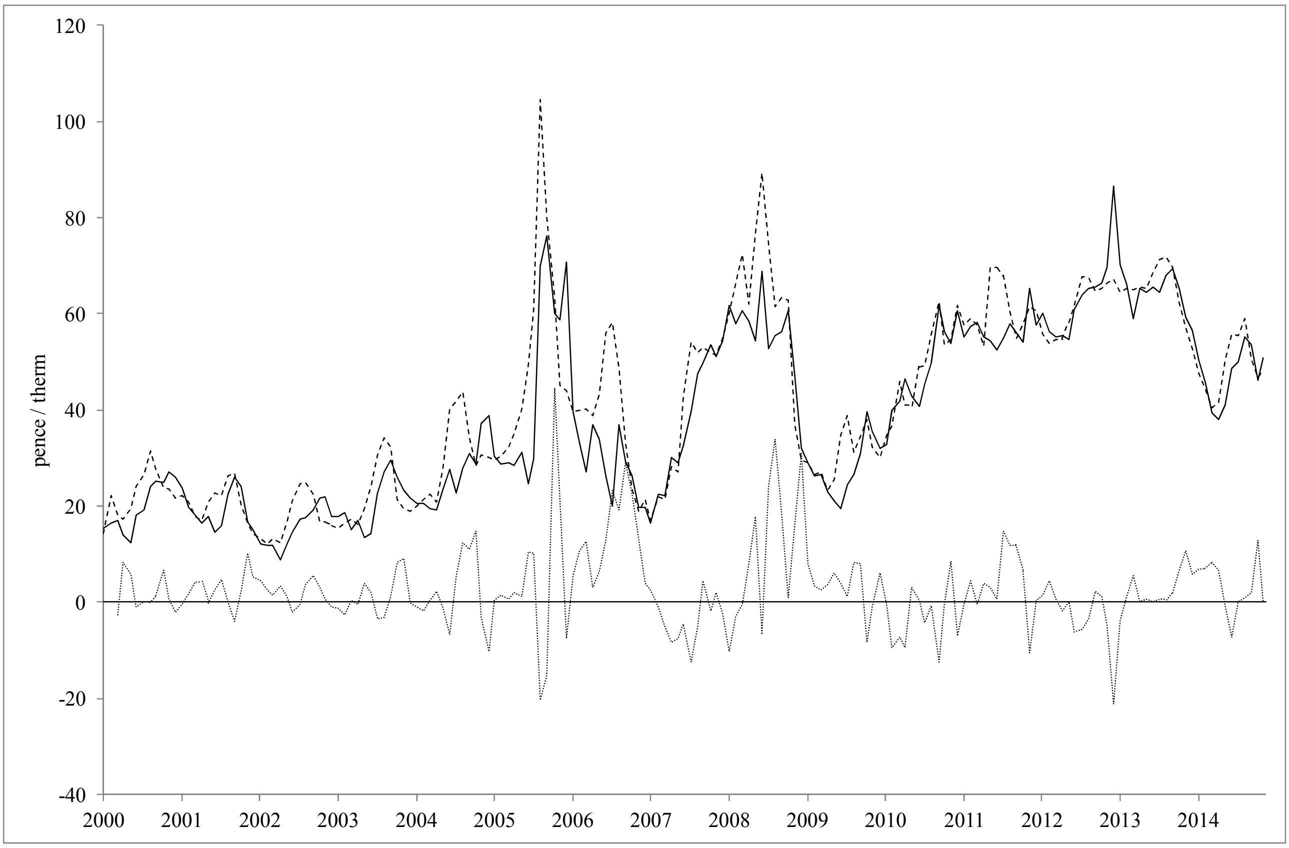


Figure 7

Ex post risk premiums (------) computed as $F(t\text{–}j,t) - S(t)$, for j = 3, 4, 5 and 6 months; and rollover premiums (——) computed as $[F(t-1,t)-S(t)]+\sum_{k=1}^{j-1}\left[F(t-(k+1),t-(k-1))-F(t-k,t-(k-1))\right]$ for j = 3, 4, 5 and 6 months.

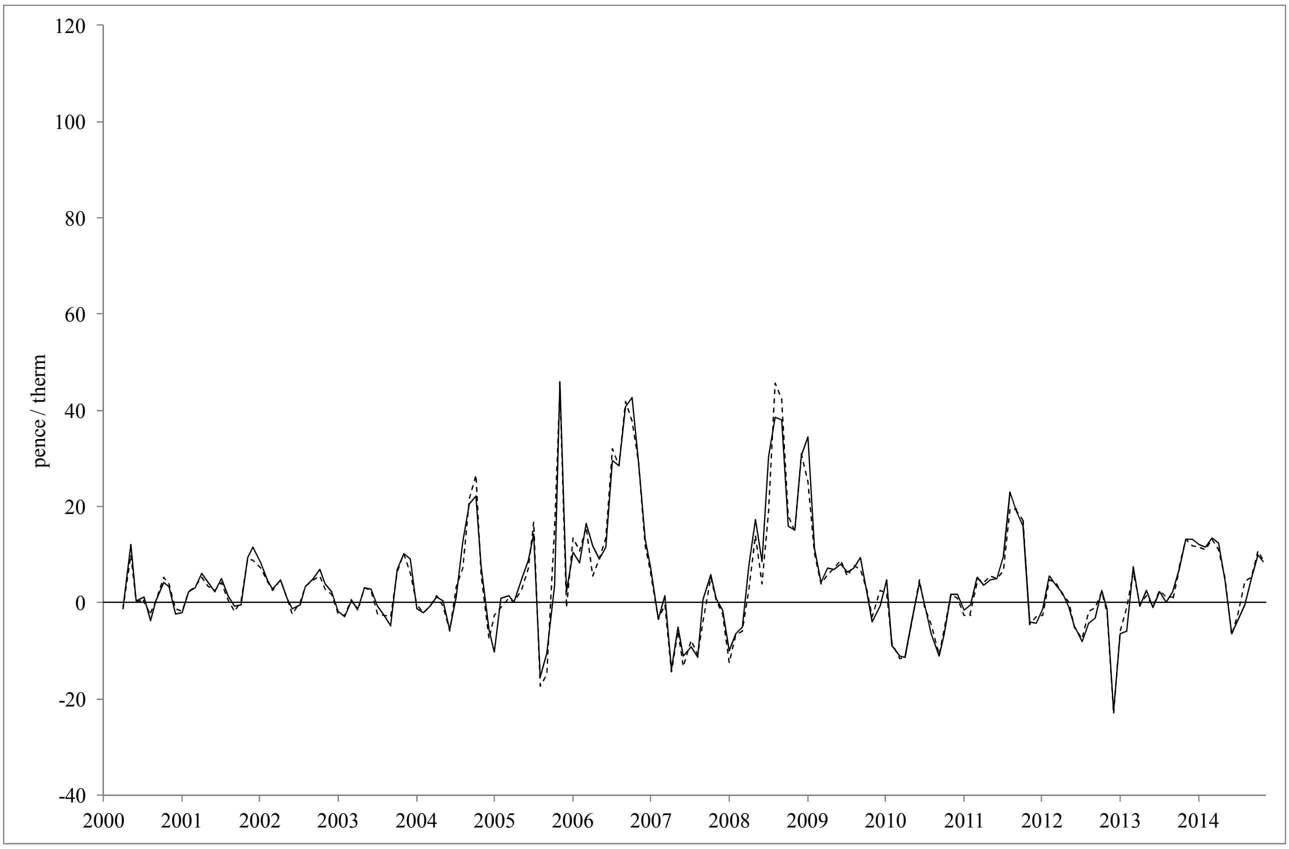


Figure 7(a). Three months prior to delivery.

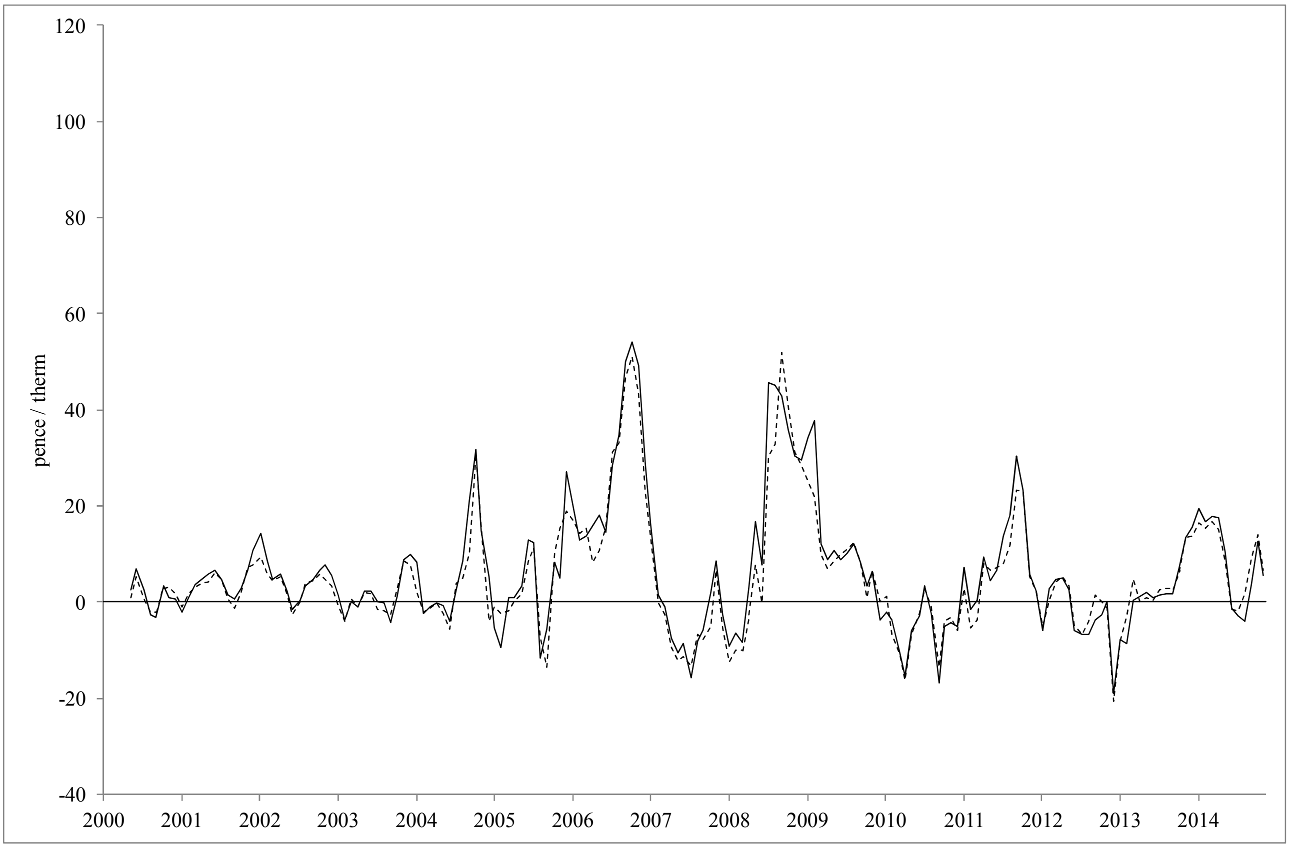


Figure 7(b). Four months prior to delivery.

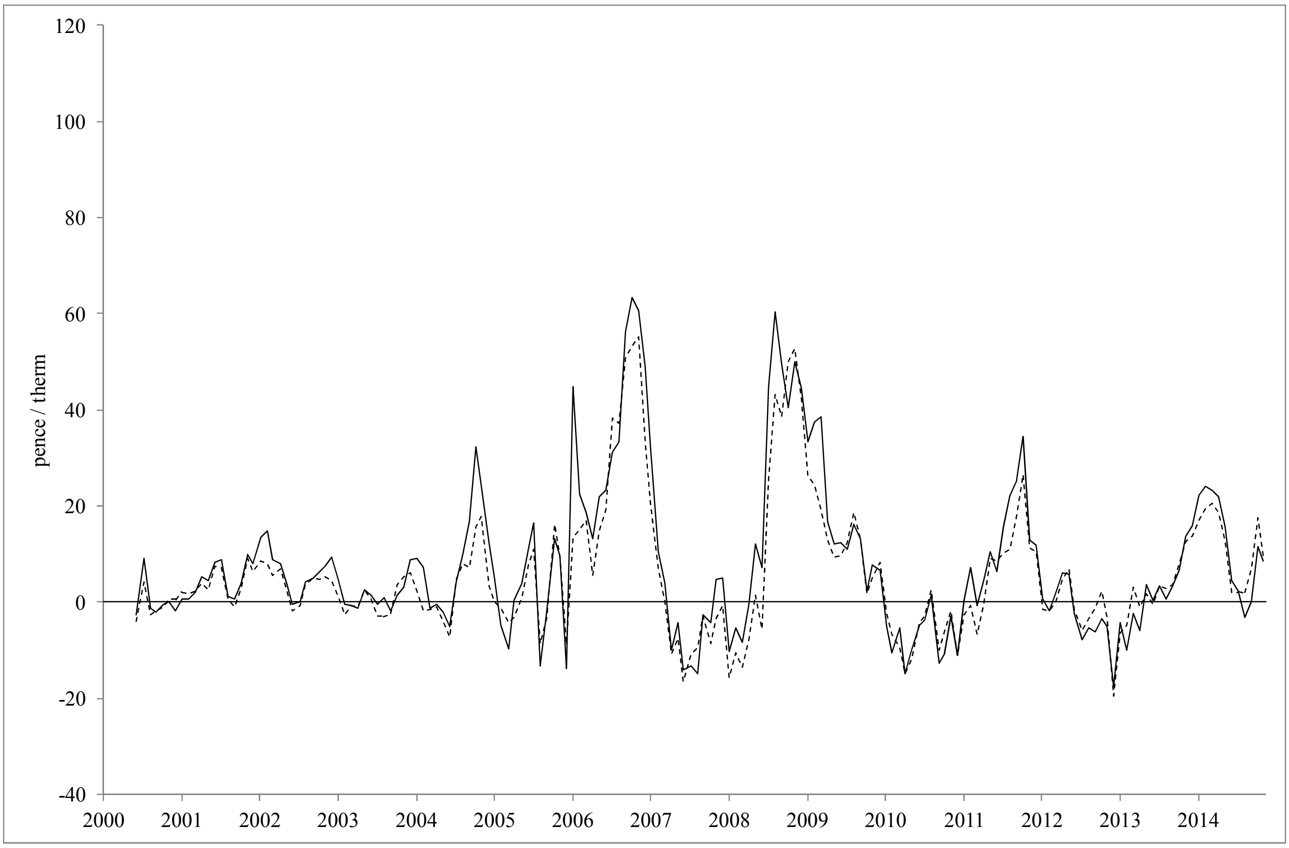


Figure 7(c). Five months prior to delivery.

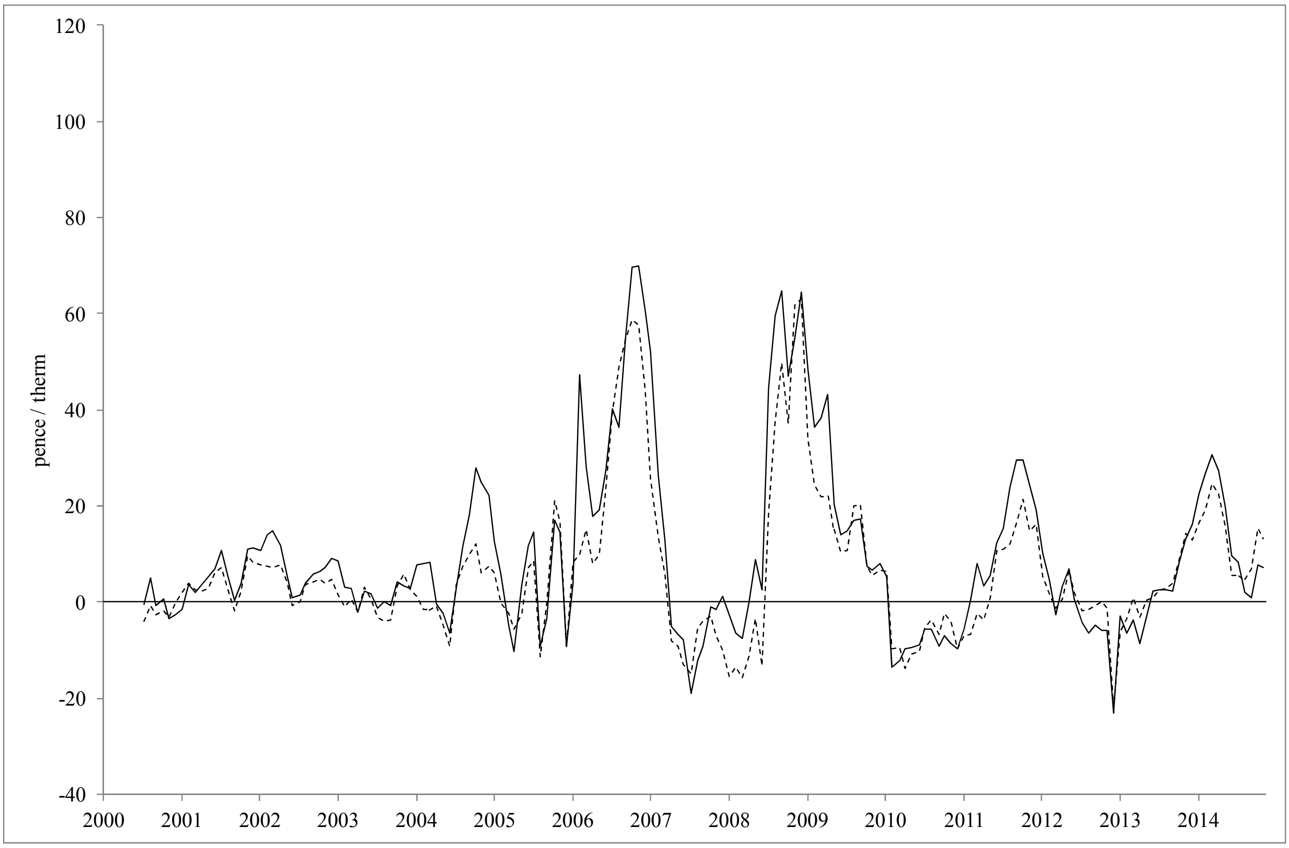
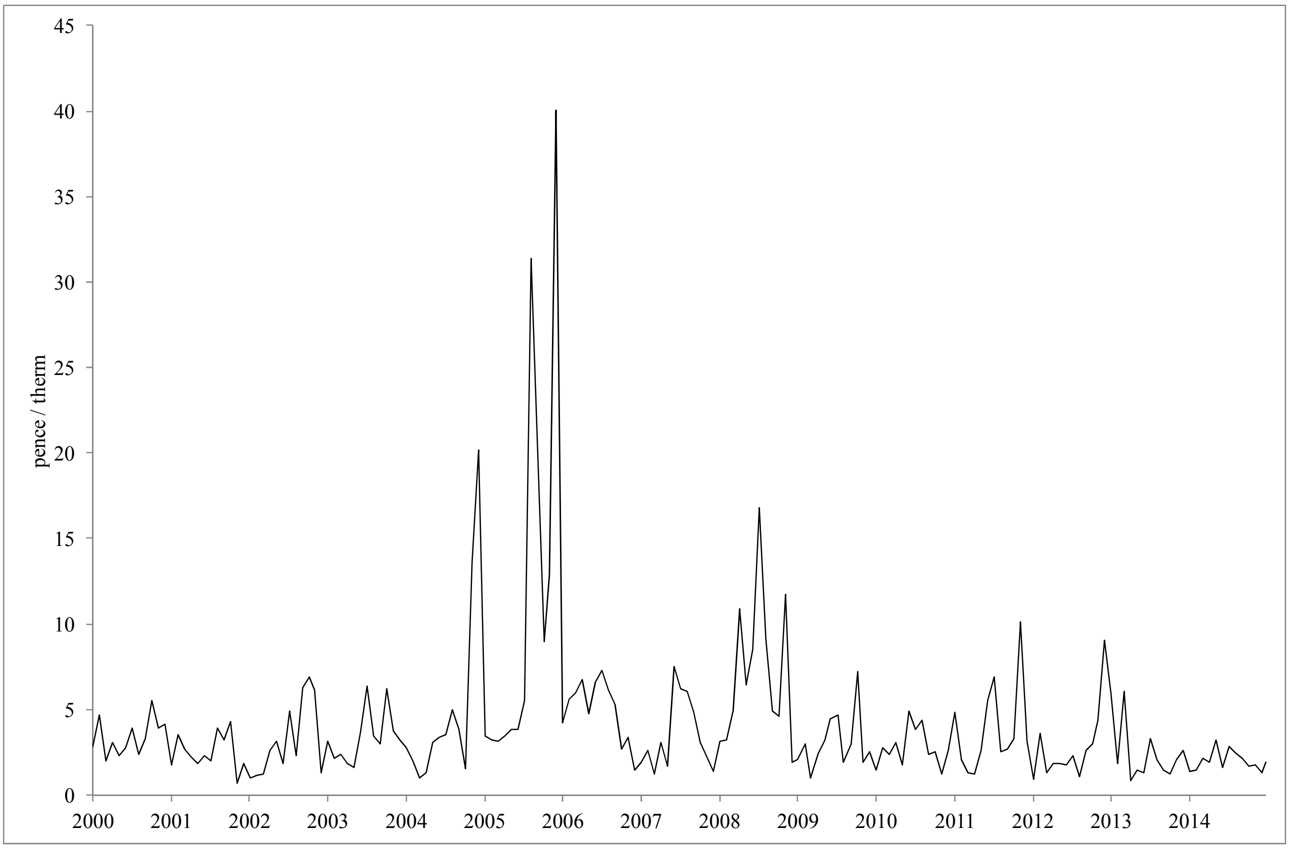


Figure 7(d). Six months prior to delivery.

Figure 8. Volatility of the system average price

The standard deviation of the system average price for each month in the sample.



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