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Dutch electricity futures market analysis: the effect of illiquidity on the risk premium

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Abstract

This analysis examines the futures market for electricity in the Netherlands with a focus on the last period before maturity of the contract. As electricity cannot be stored the pricing of futures differs from other energy commodities by including a risk premium. The analysis splits the electricity market in base and peak contracts and finds presence of the risk premium in the Dutch power market, which is shown to be negative on average. A negative risk premium indicates a discount on prices of futures contracts over the average spot price during delivery. Differences between peak and base contracts are found as the last month before maturity closes in. Base futures risk premia turn out to switch positive but the risk premia on peak futures remains negative. With the negative overall risk premium a discount is given on the futures price as time to maturity is far away, but when time to maturity closes in the discount diminishes. Next the returns from rolling forward the contract, the roll returns, are examined. Rolling forward the contracts provides positive returns on average but negative ones near maturity which demonstrates that close to maturity contracts are worth less than longer to maturity contracts. The decreasing discount over time but negative roll return near maturity indicates that holding a contract longer increases value but only up to a point where holding the same contract diminishes value compared to holding next months contract. Finally through testing multiple regression models on three different liquidity variables a link is established between liquidity in the market and the risk premium. An increased liquidity in all tested cases, except for one, reduced the discount on future prices. Vice versa more illiquid markets increased this difference through a negative relationship with the risk premium.

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1 Introduction

Over the year 2018 energy commodity prices were one of the main targets of the trade war between the United States and China, this has effected prices to an average expected increase of 33% according to the World Bank (2019). The year 2018 demonstrates the volatile characteristic of energy commodity prices. To limit the risks aligned with this volatility the usage of futures contracts has been common practice in the market since the beginning of the 1980s. Pricing of the futures contracts based on the pricing theory which forms a futures price from the spot price, adjusted for opportunity and storage costs and a convenience yield over the time left until maturity of the contract. But electricity, in contrast to other energy commodities, cannot yet be reliably stored on a large scale and retain economic feasibility. Pricing of electricity futures contracts thus changed accordingly with the expectations theory. Fama & French (1987) started the expectations theory in which not storage costs and convenience yields but a risk premium resembles the difference between (expected) spot prices and future contract prices. However back then electricity markets were mostly nationalized and the pricing theory was originated for other energy commodities. Proving the usage in electricity futures contracts did not occur until Longstaff & Wang (2004) could link the risk premium with the economic factors: volatility of unexpected changes in demand, spot prices and total revenues. Since then, the theory has been found in various studies but the sign of the risk premium and the influencing factors behind it remain to be inconsistent throughout the literature.
Meanwhile research related to the revenues originating from trading in these energy future contracts split the total investment return into four individual components: spot, collateral, diversification and roll return. The last arising when near maturity future contracts are rolled over to longer to maturity future contracts as the holder does not wish to execute. Holders of electricity future contracts have increased incentives, compared to holders of storable energy future contracts, to roll their contract forward since maturity in electricity futures requires execution through consumption or supply without storage possibilities. For storable energy commodity markets, such as oil or gas, these roll returns are predominantly positive, which originates from increasing future prices that converge towards the spot price as maturity closes in. Near maturity futures, which are sold by these speculators, are thus sold at higher rates than long to maturity futures, which are bought, apprehending a positive return. A positive roll return often indicates a market in backwardation in which despite expensive storage costs, physically holding the commodity has a bigger value than holding a futures contract. The positive or negative risk premium can often induce a positive or negative roll return.

Most studies in academic literature find on average positive risk premia for electricity future markets which can indicate negative roll returns and a contango market situation. This would suggest that the movement of electricity prices opposes that of the movement of other energy commodities. However Cartea & Villaplana (2008) showed that the risk premium does decrease when demand volatility is low while capacity risks are still high, and Bevin-McCrimmon et al. (2018) showed a positive relationship between the markets liquidity and the risk premium. But all, to the author known, conducted researches focus on large periodical returns. This paper looks at the risk premium and roll return for electricity futures in the Dutch power market as expiration of the contract nears. During this period, close to maturity of the contract, hedgers try to roll over their positions before the last trading day and without storage possibilities capacity risks will stay the same. Therefore it is argued that electricity futures contracts should show similar price behaviour near maturity as difficult to store commodities do, thus opposing what most studies find for the overall market.

Rising futures prices near maturity towards convergence from backwardation will result in positive roll returns indicating markets in backwardation and negative risk premia. The research question examined in this paper states:

Are electricity futures contract markets in backwardation as maturity of the contracts closes in?

In order to answer this question three hypothesis are tested related to the futures market. To begin the presence of a risk premium in the Dutch electricity futures market is tested by comparing mean values of the roll and spot returns. The mean difference can be rejected to be zero or negative, thus indicating the presence of a risk premium in the market. Secondly the mean roll return for rolling forward the futures contract one month before maturity is examined to be larger than zero, which would give a first suggestion of a market in backwardation. This rejection cannot be formed and in contrast a contango market through negative roll returns in the month before execution of the contract appears to be more likely. Roll returns rolled forward before the last month do appear to be positive. Finally a difference in risk premia is found present between base and peak contracts. Three different liquidity measurements are tested for a relationship with the risk premium beginning with Amihud's (Il)liquidity measurement which is expected to show a positive relationship with the risk premium as a less liquid market lowers security of the contracts value. The estimated relationships, tested through regression estimates, between the risk premium and the illiquidity measurement however indicate a negative relationship. But as it is shown that the risk premium in the examined data is negative in a majority of the cases this makes sense as illiquidity would increase the discount on futures contracts over spot prices. This indicates that holding the contract longer on average increases its relative value towards the spot price and futures with a longer time to maturity. But only up to a point when holding it further diminishes value compared to holding next months future. Overall it cannot be concluded that futures contract markets are in backwardation as maturity closes in.

The majority of research on electricity futures price behaviour either focuses on risk premia or roll-returns for investments in commodities. Few articles investigate the roll-returns specifically for electricity future contracts and similarly few focus on risk premia near maturity by using a continuing data set. This research focuses and links these two aspects together while preforming its regression models on a panel data set instead over a time series set.
In chapter two an overview of key characteristics of the electricity trading markets are given which can be skipped by those already aware of the market situations and rolling forward processes of a futures contract. Chapter three provides a summary of the existing literature and theories on pricing and return components as well as the hypothesis tested. Chapter four shows the methods used to test the hypothesis on the data, which is described in chapter five. In chapter six the results are shown that are concluded and discussed in chapter seven.

2 Electricity Trading Markets

Power markets are of the few remaining regional markets in a globalized economic world as transportation of electricity is solely possible through high-voltage networks known as grids. This limitation requires suppliers and consumers to be connected and close to each other, with significant transportation losses over extended distances, therewith preventing a global network. The grid requires constant balance between supply and demand regardless of its volatile characteristics. Volatility in demand, and to a lesser extend production, has split power trading in three markets differentiated on time frame. For the smallest time frame (15 minutes) the intraday market balances the grid, the middle time frame balances daily supply and demand on the day-ahead market and the futures market operates the long term contracts. Necessity for the intraday market arises from small differences in weather outcomes and day to day differences in consumption, in fewer cases the intraday market also balances after a loss of a generating facility. One day previous to the delivery day the TSO (transmission systems operator) balances the day-ahead market, here parties involved can buy and sell electricity to balance out their portfolio. Each party involved is obligated to maintain a daily balanced portfolio in which it shows to have acquired enough capacity on the market specific for their usage level. The third market, the financial market, provides the ability to trade in long term contracts with time frames ranging from days to years. Publicly traded deals between parties on an exchange are called futures whilst privately traded deals are forwards, on the futures market three repeating patterns occur.

Firstly all energy markets are influenced by seasonality as pointed out by among others Aggarwal et al. (2009), weather differences between the four seasons influences demand and supply. On short term markets electricity consumption shows differences throughout the week and within each day, thus a split is made between base and peak hours. Peak hours occur during the working day and base hours hold up the rest, peak hours on average show a bigger demand in power and accustomed higher prices per megawatt hour. This distinction is also found within futures markets, positions in both peak and base future contracts attain rights to receive or deliver an equally distributed amount of electricity for a set price, but just throughout that specific period. Secondly price spikes influence spot market prices with average annual price impact estimations between 20-30%. This despite them occurring in less than 1% of all hours throughout the year Higgs & Worthington (2008). The impact of spikes ripples through to futures market prices. Thirdly the volatility of electricity markets tends to be price dependent. There is a correlation between price levels and availability of electricity as generation of electricity within a grid / network contemplates from a variety of generators. Each generator has a different marginal level of costs for a MWh production stemming from the differences in power plants. The difference in marginal costs swifts the economically feasible ramp up starting point to varying prices. Resulting in a market in which the level of demand, initiates the production ramp up or down of varying generating facilities resulting in more volatility.

2.1 Commodity futures contracts

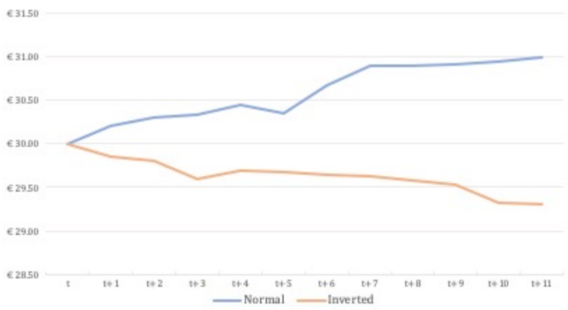
Futures contracts allow traders to sell (short) or buy (long) underlying assets in advance against predetermined prices, therewith transferring associated price risks. The price for such future contracts is set on a public exchange by eliminating bid ask spreads. Both parties are, from the deal moment onward, obligated to execute the contract by either delivering or receiving the commodity. Settling a contract can occur in two forms depending on the contract: physical delivery or financial settlement. This obligation holds at the time of maturity independent of the actual spot price of the underlying commodity at execution moment. However up until the last trading day both parties can still independently trade the attained obligations.

Futures contracts' differ from other derivative contracts in some characteristics. The contract can only be traded on public exchanges and cannot be bilaterally agreed upon as is the case for forward contracts. Next each futures contract reflects a standardized quantity and delivery moment which are beforehand determined by the exchange operator. The operator also ensures quality, delivery, payment and solvability of the opposing party. This limits the risks attained with a transaction, in example default risk is limited as the exchange operator is able to ensure solvability. For ensuring this solvability it holds strict criteria to enter the market floor and invoices both parties an initial margin payment per deal. During the period from deal closure to maturity the exchange operator daily credits or debits margin accounts of both parties against current prices. Minimal bandwidths are held for parties' accounts, which are enforced with price or trading limits. The limited exposition to risk and the standardization of futures contracts increases liquidity and efficiency within the market. Not only do more liquid markets correlate with higher efficiency through economies of scale, they also provide a more secure contract value. Efficiency on its turn lowers barriers to enter and reduces costs which increases liquidity, creating a loop.

2.2 Market situation

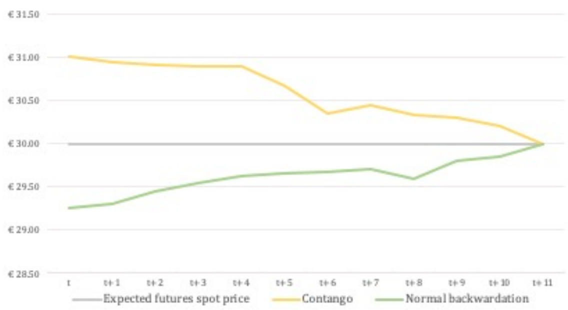
By looking at multiple futures contract prices with varying times to maturity but a similar underlying commodity a price development over time gets visible. Such graphs provide a snapshot of the current futures prices at various delivery dates. Rising future prices over time are "normal" curves, "inverted" curves represent falling prices. A normal situation implies that either the expected future spot price or the positive difference between spot and future price increases as time to maturity expands. Prices for future contracts are higher as the time to maturity of the contract increases. An inverted market exists when the spot price today is higher than the price of a future. Prices are expected to fall in the future and therefore future prices for contracts with a longer time to maturity are lower. These situations can occur when in example production has been impacted, both processes are graphically displayed in figure 1.

Figure 1: Futures curve prospects



Hypothetical futures curve of multiple contracts with differing maturing dates

Figure 2: Convergence of a futures contract



Different price converging paths to maturity for a futures contract

Looking at a single contracts price development over time, figure 2 shows two possible scenario's. The contango line represents a futures contract which starts at a higher price than the expected spot price of the commodity at maturity ($E(S_T)$). Holding a future, the right to a commodity, is in this case valued more than holding the physical commodity itself. Hedgers like for example airlines can induce a contango market when they desire to hedge the price risks associated with kerosene consumption.

In order to hedge against price risks they open a long position on kerosene. The contracts ensure the delivery of kerosene for a fixed price, but the price risks associated with hedged kerosene need to be held by another party. A majority of these risks are held by speculators who, on average, have the need to profit from the investments. Therefore, parties long on the commodity need to pay a premium in their contracts on top of the expected spot price at time of maturity inducing a contango situation. Futures contracts set in contango market conditions converge with falling prices as maturity reaches. Equation 1 represents a market in contango.

$$F_{t,T} > E(S_T) \tag{1}$$

A flipped situation indicates markets being in backwardation. Thus, the expected spot price of the commodity at the time of maturity of the futures contract is higher than the current price of the futures contract, see equation 2. Indicating that physically holding the commodity has more value than holding a future claim on the commodity. A market in backwardation occurs when i.e. power producers want to differentiate their business risks from the commodity price risk. In such a situation the power producer wants to hedge the commodity price risk by taking a short position in electricity. As this has extra value the producer is willing to settle the contract for a lower price than the expected spot price at time to maturity. Speculators on the other hand require a premium for bearing the obtained risks. Futures contracts set in backwardated market conditions converge with rising prices as maturity reaches.

$$E(S_T) > F_{t,T} \tag{2}$$

Futures contract prices ultimately always converge towards the expected spot price of the commodity at time of expiration of the contract, as at that moment the future is equal to a spot contract. Convergence towards this moment through in and decreasing prices impact investment decisions.

2.3 Rolling over of futures contracts

As a mature contract obligates its holders to settle the deal, converging prices are watched closely by those involved. In principle the goal of a futures contract is to settle but in reality only 2% of all occurring trades actually resemble this New York Mercantile Exchange Publications Office (n.d.). The vast majority of deals are second hand trades of traders who find value in the financial aspect of the product. Parties with such intentions do (often) wish to maintain their position beyond contract maturity instead of settlement. Maintaining the position is achieved by rolling-over the futures contract. Rolling over of futures contracts is common practice and usually occurs through one of these three processes:

- Closing the position on the financial market by reselling the futures contract you already hold to another party. Reestablishing the previous position through buying the same position on an exchange but with a longer time to maturity
- Offsetting the contract with an equivalent but opposing futures position with similar maturity, therewith offsetting the net holding position to zero. After witch the party re-establishes the old position as it used to hold but with a longer time to maturity
- Offsetting the contract with an equivalent but opposing position on the day-ahead or spot market, maturing the futures contract and settle with the opposing position. Reestablishing the futures position but with a longer time to maturity.

3 Theoretical Background

Electricity futures contracts serve both the physical economy as the financial markets, but as academic research still debates on the pricing theory determining the movement of prices remains difficult. This chapter explains the two most commonly used theories for pricing futures contracts. After this the composition of returns from investments in futures contracts is explored, in which the roll return concept is explained, as this can provide a better analysis of future prices. Finally hypothesis are stated in order to answer the research question.

3.1 Pricing theory

From a principle idea futures contracts hold claim to the exact same asset, the underlying commodity, as when one owns the physical product. Claiming the same asset should be priced the same regardless of the construction of the claim, thus the price of a futures contract theoretically should equal the spot price of the underlying asset (S_t). However, holding a futures contract is different from holding the physical asset as a futures contract holder is able to invest the cash value until maturity of the contract is reached as it only then has to pay, whilst the holder of the asset does not have this opportunity. On the contrary the holders of certain assets, such as equities, can receive dividends which future contracts do not pay. To compensate for this the price of a futures contract ($F_{t,T}$) consists of the spot price of the underlying asset multiplied with the exponential operator to the power of the risk-free rate (r) minus the costs to carry or dividend rate (q). To adjust this towards the length of the time until maturity the exponential power is multiplied with a time to maturity factor ($T - t$). This futures contract price relationship is shown in equation 3.

$$F_{t,T} = S_t e^{(r-q)(T-t)} \tag{3}$$

Despite similarity in pricing dynamics for all futures different underlying commodities require different pricing methods. Commodities, in contrast to equity, do not pay dividends when the underlying asset is held and therefore function 3 cannot be used. In contrary commodities often cost money to hold with storage costs, accordingly futures prices do not compensate for dividends but for storage costs (c). These storage costs range from renting a warehouse or tanker to insuring the product and maintaining it's quality over time. Especially quality maintenance can be challenging when agricultural products such as fruits and cattle are stored. Opposing the costs to store, holding a commodity does bring additional advantages as facilities that use the commodity as a raw material can continue production despite market circumstances. This benefit is a marginal benefit with diminishing added value as storage levels rise Nielsen & Schwartz (2004), but is significant. Another advantage arises when commodity stocks are held and price fluctuations provide financial gains. The compensation for possible advantages of physically holding an asset over holding a future is represented by the convenience yield (y) when pricing the future. Mathematically the storage costs and convenience yield can be seen as negative and positive dividends throughout the holding period, converting equation 3 into 4.

$$F_{t,T} = S_t e^{(r+c-y)(T-t)} \tag{4}$$

A contango market implies that the risk free rate, storage costs and convenience yield net out positive, this reverses in a market in backwardation. Equation 4 uses a storage costs of the commodity reflected in percentages of the spot price of the commodity, when storage costs are given with a monetary value the following formula applies:

$$F_{t,T} = S_t e^{(r-y)(T-t)} + C e^{(r-y)(T-t)} \tag{5}$$

3.2 Risk premium

However, as electricity is de facto impossible to store the theory of the pricing dynamics of electricity futures differs from equations 4 and 5 according to the majority of academic research. The expectations theory is proposed as a substitution which does not use storage costs as a variable to determine futures contract prices. According to the expectations theory the price of a future is the expected spot price plus a time dependent risk premium for holding the futures contract over holding the physical asset ($RP_{t,T}$). Equation 6 mathematically expresses the expectations theory.

$$F_{t,T} = E(S_T) + RP_{t,T} \tag{6}$$

The theory of risk premia can be traced to Keynes in 1930 but was widely accepted after the research by Fama & French (1987). As with the pricing theory the expectations theory futures contract price builds on the expected spot price of the underlying commodity, but at expiration date. An expected risk premium is added in order to compensate producers for bearing uncertainty of delivering or consumers for bearing uncertainty from receiving against fixed prices. Fama & French (1987) were able to prove their theory to a large extend with research on future prices of non-perfectly-storable goods such as agricultural products, however they did not forecast risk premia for electricity futures. Equation 6 is known as the ex ante premium or the predictions premium, most research however uses the ex post or realized premium, see equation 7, which uses known spot prices at maturity as it looks back upon previous times instead of expected spot prices in the future.

$$F_{t,T} - S_T = RP_{t,T} + E(S_T) - S_T \tag{7}$$

Later academic research linked the expectations theory and the futures price of electricity, however the risk premiums influencing factors remained debatable. The first significant step was taken by Longstaff & Wang (2004) who linked the risk premia for hourly spot and day-ahead forward prices to the economic factors: volatility of unexpected changes in demand, spot prices and total revenues. After this Cartea & Villaplana (2008) were able to link the forward premium for futures contracts to the economic factors demand and supply of electricity. Before this research the majority of research unveiled positive risk premia but they found that premia are higher in months with greater demand volatility and lower or negative in periods with less demand volatility. This can change market situations for a (limited) time period. They argue that negative risk premia are imposed by hedging pressure from sellers of futures contracts. A negative risk premium implies that the capacity risk outweighs the possible effects of a positive price jump in the future which can, when strong enough, induce backwardation. Douglas & Popova (2008) continue on this work and look at storability of electricity as this can decrease the amplitudes of shocks occurring from demand and supply changes. They argue that although electricity is not storable the futures premium is affected by the storability level of the underlying commodity. In similar direction Huisman & Kilic (2012) examine two futures markets with different characteristics, either predominantly perfect or predominantly imperfectly storable fuels used for generation. In their work they find that futures prices from markets in which electricity is predominantly produced by imperfectly storable fuels, such as generation from renewable sources, contain expectations about the expected spot price. In contrast futures prices in markets that generate electricity predominantly through perfectly storable fuels hold information on both expected price changes and time-varying risk premia. Afterwards Bevin-McCrimmon et al. (2018) are the first to establish the link between the risk premium and the level of liquidity in the market, and thus conclude that an illiquidity premium is priced into the risk premium of future contracts.

They examine futures contracts in New Zealand and find a positive relationship between illiquidity, through Amihud's (Il)liquidity measurement as in equation 9, and the risk premium for long to maturity futures contracts given by the relationship in equation 8.

$$\begin{aligned} RP_{t,n,T} = \alpha_{0,n,T} + \alpha_{1,n,T} Skew(S_n)_t + \alpha_2 Var(S_n)_t + \alpha_{3,n,T} S_{n,t} + \alpha_{4,n,T} Demand_t \\ + \alpha_{5,n,T} Inflow_t + \alpha_{6,n,T} Storage_t + \alpha_{7,n,T} Carbon + \alpha_{8,n,T} Oil + \\ \alpha_{9,n,T} (Il)Liquidity(F_{t,n,T}) + \sum_{j=1}^{K} \alpha_{9+j,n,T} RP_{t-j,n,T} + \sum_{j=2}^{4} \alpha_{9+k+j,n,T} Q_j + \epsilon_{t,n,T} \end{aligned} \tag{8}$$

In this regression the relationship between the risk premium of the futures market in New Zealand and the (Il)liquidity measurement of Amihud was shown for long to maturity futures contracts. The regression is an extension of the B&L model originating from Bessembinder & Lemmon (2002) which shows the risk premiums relationship with the variance ($Var(S_n)_t$), skewness ($Skew(S_n)_t$) of and the spot price ($S_{n,t}$). Bevin-McCrimmon et al. (2018) then corrected seasonality with a seasonal dummy (Q_j) and heteroskedasticity or autocorrelation within the model with the lagged risk premium variable ($RP_{t-j,n,T}$). In order to adjust for the level of demand in the New Zealands electricity market, which for a vast majority runs on hydro power dams. They included the demand of electricity, water inflow into the dam lakes and storage of electricity through water storage levels in the dam lakes as variables ($Demand_t$,$Inflow_t$ and $Storage_t$). Lastly they controlled for the changes in underlying fuel costs by including the logarithmic return of oil and carbon emission right prices (Oil and $Carbon$). The link between the risk premium and Amihud's (Il)liquidity measurement was estimated to be positive see equations 9 and 10 for calculation of the measure, more on this in section 4.2. A similar regression was run with a differing liquidity measurement, open interest. The estimated coefficient was negative which is in line with the previous found relationship as open interest diminishes, instead of increases, as the market becomes less liquid. More on the differing liquidity measures in section 4.2. Bevin-McCrimmon et al. (2018) were however not able to find significant results for these links with contracts one month before maturity, but merely for future pries longer before maturity of the contract.

$$(Il)liquidity = \frac{f_{t,t-1}}{Volume_t} \tag{9}$$

$$f_{t,t-1} = \ln \frac{F_{t,T}}{F_{t-1,T}} \tag{10}$$

In order to get to a better view of the current market situation of electricity future contracts investors returns are examined. As investors in futures do not always wish to settle the commodity they look further than spot prices alone. In the next part the returns generated by investing in commodity futures are examined with their different building blocks. Common return components are discussed as is its possible impact on futures contract investments.

3.3 Commodity futures return

In the first chapter of their book Fabozzi et al. (2008) attribute total return on commodity future investments (T_r) over four components which can each generate profit. These components are examined over a fully collateralized long only futures portfolio and are spot, collateral, diversification and roll return.

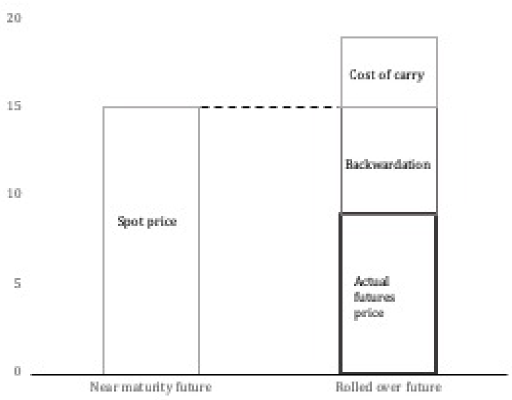
$$T_r = S_r + C_r + D_r + R_r \tag{11}$$

The standard strategy for commodity futures investments is focusing on the spot return (S_r), which reflects the increase or decrease of the spot price of the underlying commodity. Spot prices are influenced by fundamentals such as supply and demand and thus by exploration, generation and transportation of the commodity. Focusing on spot returns remains to be popular with investors but is also risky. Collateral return (C_r) is the return generated on the collateral money paid to the exchange operator who pays out dividends equal to the risk-free rate over this collateral. Therefore, these investments do bring return but this paper in contrast to Fabozzi's book does not assume fully collateralized investments. The collateral return would then only be received on the initial margin payment which for this paper is esteemed as neglectable. The same assumption is made for opportunity costs arising from not having to transmit the margin payment. Diversification return (D_r) is the return generated when an investor invests into a balanced portfolio of commodity futures instead of a single commodity. Investing in a portfolio of commodities decreases variance and volatility and increases returns. This paper however focuses on one single commodity and therefore will not experience any diversification returns, thus the co-variance between asset weight and returns is neglected similarly. As futures contracts have a set time to maturity and a set last trading date, the value of the contract converges towards the spot price of the commodity as the futures contract nears maturity. Rolling over commodity futures contracts comes with returns due to the convergence of the futures price towards the spot price over time. Roll returns (R_r) can explain a majority (of up to 91.6%) of the long-run cross-sectional variation of commodity future returns according to Erb & Harvey (2016). They also show that roll-returns highly differ between commodity sectors.

3.4 Roll return

Roll returns thus reflect the difference in future contract prices between a near maturity contract and a long(er) to maturity contract. A positive (negative) roll return correlates with a market in backwardation (contango). In backwardated markets this positive return is achieved through the accrual of gains made when longer time-to-maturity futures are bought and sold as time to maturity declines. Recall from figure 2 that in a backwardated market the prices converge towards the expected spot price by rising futures prices as maturity nears thus following a positive return. Contrary to this roll returns in contango markets are negative as prices of the futures fall in order to converge to the spot price, Stockton (2007). Both market situations can result in profits or losses for investors depending on the position held by a party. A visual presentation of a possible roll return is shown in figure 3.

Figure 3: Return Split



In their book Fabozzi et al. (2008) find that from all commodity markets investigated, only livestock and energy exhibit a consistent positive roll return over longer time periods when held in long positions. Thus, indicating a backwardated situation on average for these difficult to store commodities. For their research they diversified sectors by looking into the Goldman Sachs Sub indexes, which is predominantly invested into oil and gas for energy. In chapter five of the same book authors Viola Markert and Heinz Zimmermann found similar results and notice that a large part of the roll return is offset by subsequent spot price changes. They argue that roll returns partly reflect the expected deviation of the spot price change from the risk premium. However, a portion of roll returns is not compensated by subsequent spot price changes and could only be explained as risk premiums conditional on roll returns and expected spot price changes. These risk premia are predominantly found at agricultural products and energy products, which are again both difficult to store commodities.

3.5 Hypothesis

As the pricing theory is irrelevant for electricity futures contracts due to the inability to store power the expectations theory is looked upon. The presence of a risk premium is taken for granted in this theory, however in chapter five of the book of Fabozzi et al. (2008) Viola Market and Heinz Zimmermann could only distinguish the risk premia for difficult to store product categories. In this analysis energy products are shown to hold a risk premium but electricity is not split out from the group and individually investigated. As electricity is assumed impossible to store instead of difficult to store it is expected but unknown whether risk premia can be found in the electricity futures market. The presence of a risk premium is found by testing whether roll returns equal spot returns or not, as equality indicates that next month futures contract price difference is equal to the difference in the spot price. Demonstrating that the futures contracts would not hold any difference, through a risk premium, from spot prices. The null hypothesis for rejection is equality in the mean roll and spot return. Rejecting hypothesis zero would imply that roll returns show a risk premium component for electricity commodity futures.

$$H_0 : \overline{R_t} = \overline{S_t}$$
$$H_1 : \overline{R_t} \neq \overline{S_t}$$

After testing for the presence of a risk premium, the roll return for near maturity futures is examined to indicate whether prices are in backwardation when the contract is close to maturity. It is shown by Cartea & Villaplana (2008) that the attributed risk premium is negative when markets are in backwardation and physically holding the commodity is preferred over holding the right on the commodity. Continuing on this they correlate a backwardated market with a positive roll return. Although this correlation has been challenged it provides further indication for market conditions in the electricity futures market. A positive roll return on future contracts is expected when maturity of the contract is a month or closer away. This as a constant delivery risk remains with delivery still in the future but limitations in diversifying options occur without storage possibilities, increasing the execution probability from holding close to maturity futures. The one month rolling return for future contracts as maturity is a month or closer away should thus average out positive as prices converge towards the spot price by increasing. The second hypothesis states the expected one month forward roll return to be zero or negative as maturity is 0 to 29 days away ($\overline{R}_{t_{T-1m},T+1m}$).

$$H_2 : \overline{R}_{t_{T-1m},T+1m} \leq 0$$
$$H_3 : \overline{R}_{t_{T-1m},T+1m} > 0$$

Rejecting the second hypothesis would indicate towards a market which is in backwardation and therefore, given that a risk premium from the first hypothesis has been established, is not in contango. When the risk premium has not been established the future contract price can also be on the same level as the expected spot price and not converge at all during the roll period. The test is performed a second time for a two month forward rolling strategy in which the new contract is not one but two months away, again in the group 0 to 29 days before maturity: $\overline{R}_{t_{T-1m},T+2m}$.

When roll returns are positive and trading parties in the market try to balance their portfolios as execution comes near, liquidity in the market rises along. Whether this influences the risk premium in the Dutch electricity market is tested for through model 12. A positive relationship between Amihud's (Il)liquidity measure and the risk premium is expected as was shown by Bevin-McCrimmon et al. (2018) to be the case in the power market in New Zealand. To control for market differences the control variables used by Bevin and McCrimmon are omitted at first, resulting in regression 12:

$$RP_{t,n,T_i} = \alpha_{n,T} + \beta_{n,T}(Il)Liquidity(F_{t,n,T}) + \epsilon_{t,n,T} \tag{12}$$

As a market is less liquid the illiquidity measurement will rise and it is expected that the difference between future and spot prices rises along. Therefore a positive relationship between risk premia and illiquidity is expected, as certainty of the futures contract values lowers with illiquidity. Financial participants in the electricity futures market that hold contracts as a form of hedging are expected to want extra compensation for the accompanying risks. Thus the β from regression 12 is expected to be positive with Amihud's (Il)liquidity measurement, which rejects the fourth hypothesis. Using the open interest measurement for liquidity, which is adversely influenced than (Il)liquidity, the opposite relationship is expected and a rejection of hypothesis six indicates a negative beta.

$$H_4 : \beta_{n,T} \leq 0$$
$$H_5 : \beta_{n,T} > 0$$

$$H_6 : \beta_{n,T} \geq 0$$
$$H_7 : \beta_{n,T} < 0$$

4 Methodology

4.1 Futures return

Total return from commodity future investments comprises, as noted in paragraph 3.3, of the added sum of the spot, collateral, roll and diversification return. Roll returns originate from the difference in price of the near month futures contract prior to expiration, rolled over to a new contract with a longer time to maturity. Most academic research combines roll returns and spot returns into one return factor named the "futures return". This as it is easier to observe and an investor cannot influence roll or spot returns for a commodity therefore relying on the market. The futures return is equal to the relative change of the futures contract prices as it passes over time. Futures return is in its construction uncollateralized since the return is focused on one commodity and stands for the return from passively investing in a long position of future contracts that are continuously rolled forward thus extending the execution date.

$$\begin{aligned} \textit{Commodity return} &= \textit{Collateral return} + \textit{Futures return} \\ \textit{Futures return} &= \textit{Spot return} + \textit{Roll return} \end{aligned} \tag{13}$$

Equation 13 provides the theoretical possibility to look at one futures contract and split the return into the two components spot and roll return. Splitting the return is in reality not possible as one cannot obtain only the roll return nor only the spot return without the other return. Though the method is useful for research as it becomes possible to attribute price changes to characteristics of the contract / commodity. As previously mentioned the futures return is the relative change of the futures contract price passing over time and gaining or losing monetary value. The spot return reflects the increase or decrease of the spot price of the underlying commodity over time. Gorton & Rouwenhorst (2004) were one of the first that showed that the spot price of a future can be mimicked with the future price closest known to maturity of the contract, as future contracts converge to the spot price. The difference between this price and the current price is used as a mimic of the spot return accounted for. Equation 13 further implies that the roll return can be found by subtracting the spot return from the overall futures return. The futures return is the total return made from the investment.

$$\textit{Roll return} = \textit{Futures return} - \textit{Spot return} = \Delta F_{t,t-1} - \Delta S_{t,t-1} \tag{14}$$

Prices as in table 1 provide the following roll returns for a long position on January delivery with its last trading day on the 30th of December, rolled over into a February contract. The trade corresponds to a negative roll return of 2.16%, when rolled over on the 30th of December. This is calculated by subtracting the negative spot return from the negative futures return. The futures return is the return established from a difference in price of the new contract, and the spot return established from the the difference in the spot price between contracts. A negative roll return associated with the period implies a contango market situation as the slope on the convergence line of the futures price towards the spot price is negative. The party holding the contract will again roll the contract next month and the month after until infinity, therewith providing an endless hedge. This is crucial as the trader deposits a margin payment and thus profits like the -2.16% are never actually made without the spot and collateral return. The periods roll return can account for the slope of the price change during that period according to Till (2006).

$$\begin{aligned} \textit{Futures return} &= \frac{F_{t,T} - F_{t-1,T}}{F_{t-1,T}} = \frac{50.03 - 51.55}{51.55} = -2.95\% \\ \textit{Spot return} &= \frac{F_{t,T} - F_{t-1,t}}{F_{t-1,t}} = \frac{50.03 - 50.43}{50.43} = -0.79\% \\ \textit{Roll return} &= \Delta F_{t,t-1} - \Delta S_{t,t-1} = (-2.95\%) - (-0.79\%) = -2.16\% \end{aligned} \tag{15}$$

Table 1: Hypothetical pricing pattern

Electricity future price		**Contract**		
Date	Jan	Feb	Mar	Apr
29/12	51.58	52.46	50.71	48.11
30/12	50.43	51.55	49.75	47.65
31/12		51.55	49.75	47.65
...		...	...	...
28/01		48.00	45.63	44.65
29/01		50.03	46.48	45.36

To test whether the mean roll return equals the mean spot return, and thus to check for a risk premium component within the commodity contract prices, a mean difference test is conducted. Before this the normality of distribution of the observation is checked in order to determine the test type, t-test or z-test. As both the spot and roll return are constructed from the same observations and dependent upon each other a paired test is conducted. The null hypothesis of the test is that the mean difference between the roll return mean and spot return mean is zero. Rejecting the null hypothesis of the test would mean a difference between the mean values of the roll return and the spot return, thus rejecting the null hypothesis as stated in section 3.5, and would mean that their is a risk premium component. This test will be conducted twice, as will all tests, once for peak and once for base contracts. As the roll return is checked for rolling forward both one and two months ahead the test is conducted again to confirm the results. A comparable test will be conducted to test the second and alternative hypothesis. The second test however does not test a difference in means but tests a level of the mean roll return when rolling forward is conducted 0 to 29 days before the last trading day. Null hypothesis of the test is a mean that cannot be rejected to be zero, therefore rejecting the test hypothesis would indicate the possibility to reject a mean of zero for the roll return. The test also suggests the mean to be either positive or negative, assuming null is rejected. However as it is a one-sample test the p-values have to be checked with the mean and t value, as a negative t can induce wrong p level indications for non zero means.

4.2 Liquidity variables

In their research Bevin-McCrimmon et al. (2018) examine four different models and their explanatory power for the correlation between risk premia and liquidity in the market. Starting with the model of Bessembinder & Lemmon (2002) that links risk premia to skewness and variance of the spot price and the spot price alone up to equation 8 which links liquidity in the market with the risk premium. Measuring liquidity is conducted through three variables: Amihud's (Il)liquidity measure, open interest and volume. The (Il)liquidity ratio as developed by Amihud (2002) consists of the daily return from futures price difference ($f_{t,t-1}$) over the amount of daily traded contracts ($Volume_t$). The measurement can be seen as the "daily price impact of the order flow". As it is shown in both the article of Bevin-McCrimmon et al. (2018) as in an earlier article of Marshall et al. (2011) to have the best and most consistent explanatory power while tested on commodity futures contracts, this measure will be used and is present in the regression formulas stated. Constructing the measurement is conducted as equations 16 and 17 indicate. A more liquid market will result in a lower level of (Il)liquidity as traded volumes go up and lower changes in daily price difference with less power from one single trade over all other conducted trades.

$$(Il)liquidity = \frac{f_{t,t-1}}{Volume_t} \tag{16}$$

$$f_{t,t-1} = \ln \frac{F_{t,T}}{F_{t-1,T}} \tag{17}$$

However as is observable in chapter 5 the traded volumes, or $Volume_t$, are in 89% of the observations zero or not available thus eliminating the possibility to construct the (Il)liquidity measurement. Therefore using $Volume_t$ as a measurement on its own is skipped and the (Il)liquidity measurement of Amihud can only be used with caution.

The open interest measurement is widely used in academic research as an indicator for liquidity in the market and resembles the amount of contracts in existence which are not sold at the moment. Open interest is linked with hedging activity in a market as hedgers often do not hold contracts up to the end of the trading day. A higher measurement of open interest thus resembles a more liquid market, opposing the (Il)liquidity measurement. Open interest is a measurement of liquidity instead of illiquidity. However some research argues that open interest can also resemble a less liquid market as the markets have a surplus in either short or long parties and desired deals does do no occur leaving contracts open. This view is however not widely supported in the literature.

Lastly the standard deviation of the logarithmic return of the settlement prices of power futures contracts is used as a measure of liquidity. The measure looks at today's return on the settlement price over yesterdays return, as in equation 16, compared with the mean return of the previous 60 days results. Thus the measure measures the abnormality of settlement price changes of today over the past two months. Equation 18 shows the calculation of the measurement with n is 60. An increase in the standard deviations measure occurs as the market is less liquid and a single trade has a more severe impact on the settlement price and the daily return, thus the measure is an illiquidity measure like the one of Amihud.

$$\sigma_{t,t-60} = \sqrt{\frac{\sum(f_{t,t-1} - \bar{f_{t,t-1}})^2}{(n-1)}} \tag{18}$$

4.3 Risk premium modelling

The ex-post risk or realized risk premium is used as this method has the advantage of using historic prices instead of replicating expected prices which are known to be inaccurate. As the data-set used consists solely of historic data the actual spot price is known. The ex-post risk premium consists of the difference between the daily futures price and the average spot price during the execution month. In order to make it proportionate to prices the difference is divided over the average spot price as is done by Shawky et al. (2003). This in order to show the relative power of the risk premium instead of skewed results due to seasonality.

$$RP_{t,T} = \frac{F_{t,T} - \bar{S_{t,T}}}{\bar{S_{t,T}}} \tag{19}$$

The actual spot price for a contract is the average day-ahead price on the APX Dutch Power market during the delivery month of the contract as day-ahead prices are common substitutes for spot prices. While futures are only traded on working days the day-ahead prices are given for the period Sunday - Thursday. These trading days, as they are day-ahead, do represent the same period as futures. An average is calculated for both a peak and a base price per delivery month of the contracts.

Although previous research on the risk premia of electricity futures contracts do find significant relationships with liquidity the data analysis is performed on a fixed time to expiration and changing time of expiration of the contracts. In other words the time to maturity of the contracts is a constant whilst the date, and thus the execution moment of the contract differs. These models thus examine the effects on a fixed time to expiration for a multitude of contracts on different dates given as though the contracts are the identical. A panel data analysis instead of these time series regressions helps to increase the explanatory power of the model by reducing colinearity, increasing the degrees of freedom and most importantly differentiating between contracts on each date. Efficiency of the estimators over such analysis increases and relationships shown are closer to reality. This since the analysis performed in this period does not assume perfect equality between each contract and time until expiration, but in contrast uses continuous data in order to adapt to changing circumstances. As the relationship between the risk premium and liquidity variables is tested the following regression is used to determine coefficient estimates with an ordinary least squares (OLS) method. The testing for a positive β in equation 20 is an OLS as used by Bevin-McCrimmon et al. (2018) but performed on a panel data set instead of multiple time series analysis. A Hausman test for correlation between the unique errors and the regressors is performed before in order to determine the appropriate regression model test. The null hypothesis is that there is no correlation and a random effects model is appropriate, the alternative hypothesis of correlation indicates the usage of a fixed effects model. All three liquidity measurements will be tested for their relationship through equation 20.

$$RP_{t,n,T_i} = \alpha_{n,T} + \beta_{n,T}(Il)Liquidity(F_{t,n,T}) + \epsilon_{t,n,T} \tag{20}$$

As the expected explanatory power of regression 20 is low irregardless of the illiquidity measurement used, due to the fact that all other influencing variables are situated in the error term, a second regression similar to equation 8 is formed. The model is adjusted towards the Dutch power market. The main focus of the test is looking at consistency in the significance and sign of the relationship between liquidity and the risk premium. As the Dutch power generating facilities run on different fuel sources than the New Zealand power system, the control variables inflow, demand and storage are excluded from the model. In contrast power in the Netherlands is largely generated by oil, coal and natural gas generation facilities, thus these prices are included in the model (Oil_t, Gas_t and $Coal_t$). Next the quarterly dummy is replaced by a variable which indicates the total level of electricity supplied in the Netherlands during the delivery period ($Load_T$), this variable better controls for seasonality through implementing total supply for each month individually. For further explanation of the used variables table 14 in the Appendix provides additional information. The extended risk premium model is constructed as follow:

$$\begin{aligned} RP_{t,n,T} = \alpha_{0,n,T} + \alpha_{1,n,T}Skew(S_n)_t + \alpha_2 Var(S_n)_t + \alpha_{3,n,T}S_{n,t} + \alpha_{4,n,T}Oil_t \\ +\alpha_{5,n,T}Gas_t + \alpha_{6,n,T}Coal_t + \alpha_{7,n,T}Carbon_t + \beta_{n,T}(Il)Liquidity(F_{t,n,T}) \\ +\alpha_{8,n,T}Load_T + \sum_{j}^{K} \alpha_{9+j,n,T}RP_{t-j,n,T} + \epsilon_{t,n,T} \end{aligned} \tag{21}$$

To achieve more robust and reliable estimations a continuing data set needs to be checked beyond the tests of Bevin-McCrimmon et al. (2018). Thus this research follows the practice set out by Fassas & Siriopoulos (2011) who test VIX futures contracts on their efficiency in panel data form instead of time series analysis. As VIX and power futures share the similar characteristic that they are impossible to store the same practice is applied.

For heteroskedasticity across time a White test is performed in which the squared residuals are regressed against the explanatory, squared explanatory variables and their product. After this the number of observations is multiplied with the R^2 to form the test statistic and tested against equality. The null hypothesis is homoskedasticity, thus if rejected heteroskedasticity across time is present and should be accounted for in the regression analysis. The second test, the Pesaran test, checks for contemporaneous correlation or cross-sectional correlation. With null-hypothesis of no cross-sectional dependence the test is rejected when contemporaneous correlation is present. However this does not automatically have to bias the estimated coefficient, it could presumably effect the variance estimates though. Thirdly the correlation of error terms over times, or serial correlation, is tested with the Wooldrige test. A pooled regression of the risk premium against the illiquidity measurement and the prior periods residual value is run. Afterwards a coefficient t-test of past residuals is tested using heteroskedastick robust standard errors, with null hypothesis of no serial correlation. Lastly a Fisher unit root test for base and peak contracts is performed to test on stationarity with the null hypothesis being no stationarity.

5 Data

All electricity futures pricing data used in the research originate from the ICE Endex exchanges of electricity futures. The products all have an execution period of a month, and a minimum trading value of 1 MW. They are all traded in Euro's and run between the 7th of October 2013 up to the 27th of February 2019, with execution periods between January 2015 and March 2019. The Dutch Power Baseload Futures are contracts for equal delivery (short position) or usage (long position) of power during the month's base hours. Base hours run from 20:00 in the evening till 08:00 in the morning during weekdays and for 24 hours in the weekend. Contrary peak hours are between 08:00 and 20:00 every weekday regardless of public holidays. The last trading day is two days prior to the first calendar day of the delivery month, the number of days left until this day is noted as TLTD (Time to Last Trading Day) in this research. Dutch Power Peakload Futures are similar contracts to the Dutch Power Baseload Futures but delivery or usage of power is completed during peak hours in the execution month. For the analysis daily settlement prices of both contract forms are collected as published in the end of day report by the ICE Endex. Settlement prices are used as these provide better information on daily pricing differences of a contract than last traded prices, this as not all days have trades occurring for each contract thus not always changing the last traded price. Since the futures markets do not at all times show significant liquidity in order to establish price differences the settlement price can be determined from both actual trades as from non-executed trading orders. This Pricing Window Methodology, and explanation, can be found with ICE Endex (n.d.). A total of 102 contracts are examined for this research, equally split between base an peak contracts. The availability of data is not always consistent as more observations are present for newer contracts as can be seen in table 2. Therefore the maximum TLTD is set at 730 or two years to increase consistency of data however still not equal.

Table 2: Descriptive table of future contract settlement prices

Peak	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
Overall	46.094	45.780	8.629	27.200	92.480	25,003
2015	51.138	50.850	4.564	40.240	63.700	5,165
2016	44.792	45.680	7.125	27.200	62.680	5,868
2017	41.571	41.280	6.061	28.400	59.700	6,206
2018	45.140	43.395	9.381	27.720	92.480	6,212
2019	56.134	52.200	12.733	37.980	89.090	1,552
Base	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
Overall	37.831	37.440	7.410	21.860	78.390	25,003
2015	42.351	41.940	3.599	33.620	52.900	5,165
2016	36.681	36.850	5.465	24.040	50.750	5,868
2017	33.726	33.735	5.021	22.010	50.650	6,206
2018	37.288	35.695	8.449	21.860	78.390	6,212
2019	45.720	42.680	11.760	28.840	74.030	1,552

All numbers are noted in Euro's, except for the amount of observations

As visible the amount of observations in 2019 is significantly less than in the other years which is explained from the fact that merely the first three month contracts are used. This also explains higher mean prices in 2019 as the earliest months in a year, in which temperatures are coldest, see the highest prices. The years 2015 and 2016 show less observations than 2017 and 2018, which is due to the decreasing availability of data in Bloomberg as time passes. Further mean and median prices seem to show relative consistency with the lowest means in 2017 and a consistently higher peak price than base price. The table also shows that the year 2018 saw the biggest volatility in minimum and maximum prices for both base and peak contracts.

5.1 Roll return

The roll, spot and futures returns of the contracts are calculated for each contract individually over the last six months until expiration of the contract. There are two different strategies examined, the one month and two month forward roll. The descriptive statistics of the returns can be found in table 3, which show near zero means for peak roll returns both one and two months forward. Base contracts show mean returns slightly above zero though limited. Standard deviations are high for all spot and futures returns which indicates large differences between returns from rolling over different contracts at different moments in time. In the Appendix figures 12 and 13 seem to show a seasonality factor in the roll returns as is expected, the roll returns constipate from settlement prices of the contracts which are known to have seasonality thus seasonality in roll returns is no surprise. The last three months of 2015 and the first month of 2016 show smaller amplitudes in the roll returns than the other periods, no explanation for this can be given at this point. Figure 17 appears to show mean reversion in the peak contracts one month roll return over the tested period and to a lesser extend the base contracts one month roll return in figure 16 shows similar results. This mean reversion of the roll returns could come from the known mean reversion of electricity prices. For the base contracts it appears that there is a period, between 37 and 144 days before expiration of the contract, in which the vast majority of roll returns is positive. Figure 18 with the two month roll return for base contracts indicates similar results as the one month roll return with slight differences in amplitude or exact moment of switching signs but relatively close to those of a one month roll return. The two month roll return strategy for peak contracts in figure 18 displays an interesting wave in which mean roll returns start negative when the contract is close to maturity but with an increasing maturity the roll return increases along up to the peak 75 days before maturity. Approximately 2.5 months before maturity the average two month roll return strategy for peak contracts peaks at +2.73% after which it declines with a similar wave pattern as it increased, to turn positive again just before the 180 days before maturity moment.

Table 3: Descriptive table of roll, spot and future returns

Peak	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
1m Roll Return	0.039	0.594	6.072	-22.698	19.287	6,486
1m Spot Return	3.546	0.408	21.559	-45.073	80.591	6,486
1m Futures Return	3.586	1.067	19.087	-37.154	65.865	6,486
2m Roll Return	0.057	0.991	9.724	-33.057	26.415	6,518
2m Spot Return	4.360	-0.485	26.361	-49.654	93.396	6,518
2m Futures Return	4.417	1.413	21.334	-37.154	65.865	6,518
Base	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
1m Roll Return	0.336	1.001	5.015	-20.928	12.389	6,495
1m Spot Return	3.929	1.594	19.944	-43.117	79.402	6,495
1m Futures Return	4.265	2.448	18.544	-38.107	70.310	6,495
2m Roll Return	0.286	0.998	5.021	-20.368	12.116	6,494
2m Spot Return	4.683	1.457	23.830	-45.860	86.130	6,494
2m Futures Return	4.970	2.598	22.438	-43.117	79.402	6,494

All values stated in percentages, except for observations

5.2 Risk premium and liquidity variables

With risk premium as the relative difference between the futures price and the spot price, a negative mean risk premium indicates that futures contract prices are on average cheaper than the spot price.

Visible in table 4 is that this is the average case for both peak and base contracts which can indicate that the markets are in backwardation as stated in equation 2. In table 4 it is noticed that the mean risk premium for base contracts is closer to zero than the mean risk premium for peak contracts and the median risk premium is respectively positive and negative. This difference in risk premium between base and peak contracts is graphically visible in figures 4 and 5 in which the average risk premium per TLTD is plot. The graphs show that the risk premia are positive and near zero as expiration is close, but drastically decrease as time to last trading day increases. The base contracts graph starts at around 10% where the peak contracts graph starts near 0%. A similar pattern is visible in graphs 20 and 21 in the appendix.

Figure 4: Average risk premium over TLTD - base contracts

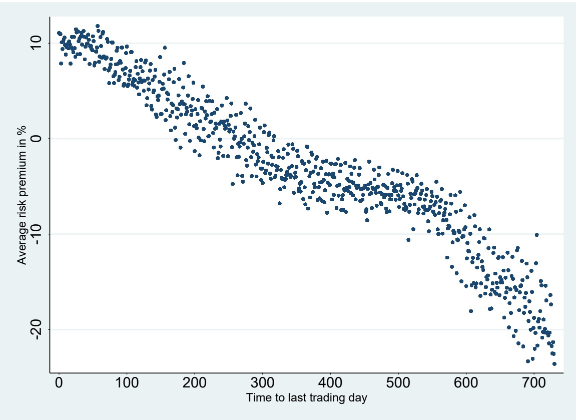
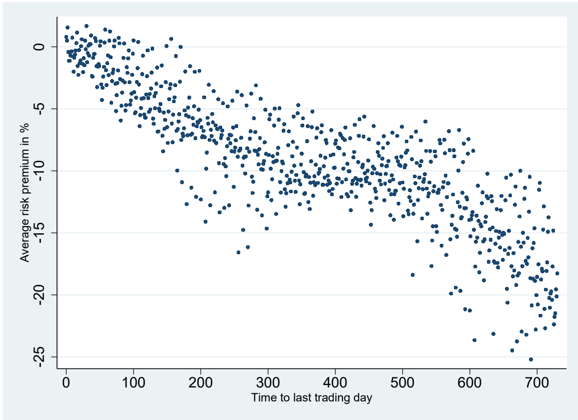


Figure 5: Average risk premium over TLTD - peak contracts



Minimum values relatively close too each other for peak and base contracts indicate similarity in downward trends. Base contracts do show a 20% higher maximum risk premium than peak contracts. As overall maximum settlement prices are higher for peak contracts which is known from table 2, this could indicate a lower correlation between future and spot prices for base contracts.

Table 4: Descriptive table of the risk premium and liquidity variables

Peak	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
Risk Premium	-0.086	-0.016	0.300	-1.758	0.819	25,003
Volume	0.817	0.000	3.817	0.000	180.000	25,003
Volume $\neq 0$	8.696	5.000	9.648	1.000	180.000	2,350
(Il)liquidity	0.000	0.000	0.000	-0.023	0.044	2,350
Open Interest	358.100	309.000	177.927	84.000	1,078.000	24,919
Std. Dev. Log. Ret.	1.013	0.948	0.345	0.398	2.148	23,749

Base	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
Risk Premium	-0.024	0.033	0.312	-1.818	1.025	25,003
Volume	2.304	0.000	7.257	0.000	150.000	25,003
Volume $\neq 0$	12.912	10.000	12.576	1.000	150.000	4,462
(Il)liquidity	0.000	0.000	0.003	-0.024	0.030	4,462
Open Interest	1,099.336	1,154.000	412.441	100.000	2,047.000	24,919
Std. Dev. Log. Ret.	1.077	1.009	0.356	0.442	2.377	23,749

Risk premium as given in equation 19, (Il)liquidity in Amihud's measurement and standard deviation of the logarithmic return noted in percentages.

In the examined set of observations, as mentioned before, not all moments in time saw trades for all contracts occur. The average amount of traded contracts ($Volume_t$) per time to last trading day is shown in figures 6 and 7. More trades occurred for base than peak contracts as is visible in table 4, but these graphs also show a skewness to the left for the occurring trades. This indicates that more contracts are traded during the last period before expiration in which liquidity in the market clearly increases, but interestingly this skewness is more severe for base contracts than peak contracts. Figure 7 is a more time-invariant graph than figure 6 with the moment with the most observation 355 days before expiration. This is just partly explainable from the fact that the average amount of traded contracts on a single day is 0.82 for peak contracts. Therefore a moment in which a contract is traded 180 times on the same day has a severe impact and thus reflecting one instead of all possibly tradeable contracts traded during that day.
Table 4 indicates that there are 25,003 observations for both peak and base contracts. However there are 22,653 moments in which the volume for peak contracts is zero or unknown and 20,541 similar moments for base contracts. The average volume without these observations is also given in table 4 in the line below $Volume_t$, with a mean value of 8.696 and 12.912 respectively for peak and base contracts.

Figure 6: Average traded volume over TLTD - base contracts

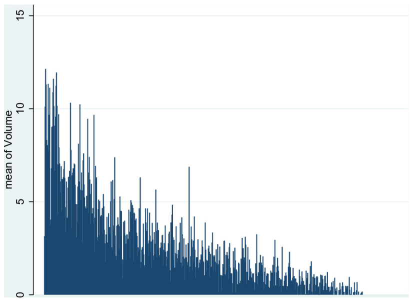
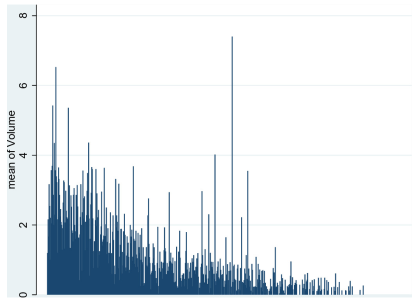


Figure 7: Average traded volume over TLTD - peak contracts



In equations 9 and 17 the formula to construct Amihud's (Il)liquidity measure is shown but the measurement merits just 6,812 out of possibly 50,006 observations. This amount is equivalent to the total amount of moments with individually observed volumes. The mean, median and standard deviation are all 0.000 for peak and base contracts. With a mean (Il)liquidity of 2.75e-04 for peak and 1.35e-04 for base contracts again the low applicability of the measurement is shown.
Of the three liquidity measurement variables open interest shows the largest difference between peak and base contracts. Base contracts report higher mean, median, standard deviation, minimum and maximum levels than peak contracts. This either indicates that demand and supply of base contracts is more imbalanced than that for peak contracts, or it implicates that base contracts markets are more liquid which is more likely.
The standard deviation of the logarithmic return of the settlement prices over the last 60 days shows the spread in price changes of the today settlement price compared with the last 60 days. The mean and median levels of near one, indicating that average daily price change differs a percent each day. The overall minimum of 0.398 and maximum of 2.377 indicates that the average differences are relatively low during the rolled 60 days period. The total amount of observations differs from the total of observations as the standard deviation over the past 60 days can only be taken from day 60 onwards and not before.

5.3 Control variables

Table 5 shows the descriptive analytics of the remaining variables used for regression 21, table 14 situated in the Appendix displays a verbal extension on definitions and sources used for the data set. All variables in table 5 show 25,003 observations except for load and carbon allowances contracts. The first is due to the unavailability of data from the IEA for the months February and March on the levels of supplied electricity in the Netherlands by the time of collecting this whilst the latter is due to the fact there were no prices available on the 29th of October 2013 and the 2nd of April 2018 for carbon allowance contracts without a clear reason.

With close to zero mean skewness of the spot price this indicates relatively normal distributed spot prices over time. Peak day-ahead spot prices are more positively skewed than base prices during the time period examined. The variance of spot prices shows severely more variance for peak spot prices, though overall average spot prices are fairly similar to the overall average futures contract price.

The rolling average price change of the generic first months futures contract over the past 30 working days can indicate the relationships between thermal fuels and risk premium. In table 5 declining means for oil and gas and increasing means for coal and carbon allowances are observed. As the risk premia means decreases over the observed time period the future oil and gas price changes are in positive relationship to the risk premium change. In contrast the (assumed) relationship between carbon allowances or coal and a risk premium are probably negative. The load factor is less generic than all other data used, as each execution months load level remains constant throughout the data set. For the last five variables no distinction could be made in the data between peak and base hours, thus no distinction is visible in the descriptive analysis.

Table 5: Descriptive table of regression variables

Peak	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
Skewness	0.603	0.550	0.903	-1.592	4.746	25,003
Variance	59.687	34.934	68.340	7.044	364.897	25,003
Spot Price	46.541	45.810	11.377	18.810	124.240	25,003
Oil	-0.649	-0.295	7.181	-24.671	18.675	25,003
Gas	-0.307	-0.786	6.946	-25.578	23.481	25,003
Coal	0.344	0.263	5.158	-18.353	20.604	25,003
Carbon Allowances	0.817	1.218	8.707	-39.553	27.531	24,981
Load	9,720.984	9,672	725.782	8,590.447	11,057.688	23,969

Base	**Mean**	**Median**	**Std. Dev.**	**Min.**	**Max.**	**Obs.**
Skewness	-0.281	-0.154	0.766	-2.709	1.857	25,003
Variance	16.305	13.581	11.722	3.024	71.291	25,003
Spot Price	35.553	35.220	7.225	11.940	69.200	25,003
Oil	-0.649	-0.295	7.181	-24.671	18.675	25,003
Gas	-0.307	-0.786	6.946	-25.578	23.481	25,003
Coal	0.344	0.263	5.158	-18.353	20.604	25,003
Carbon Allowances	0.817	1.218	8.707	-39.553	27.531	24,981
Load	9,720.984	9,672	725.782	8,590.447	11,057.688	23,969

Spot Price given in Euro's; Oil, Gas, Coal and Carbon are noted in percentages; Load is noted in MWh

6 Results

6.1 Roll return analysis

Figures 12 and 13, situated in the appendix, show seasonality in the roll return results when graphed over a date horizon, this can be explained from seasonality patterns in settlement prices for electricity futures. In figures 14 and 15 of the appendix the histograms of the peak and base one month roll and spot returns are shown. The resulting histograms for roll returns are somewhat skewed to the right whilst those for spot returns show a skewness to the left. Thus a t-test is preferred over a z-test as it tests against a student t instead of a normal distribution. The paired t-test results in table 6 indicate a rejection of equality between the roll and spot return with an extremely high probability in all scenario's. Meanwhile a positive difference cannot be rejected and is likely to be present between the means of the roll and spot return. As this rejects the null hypothesis from chapter 3.5 a risk premium component in the futures price is likely to be present as expected. Complete t-test results can be found in table 15 in the Appendix.

Table 6: T-test result for risk premium

	1 month roll		2 months roll	
Hypothesis	Peak Contracts	Base Contracts	Peak Contracts	Base Contracts
mean(diff) < 0	0.000	0.000	0.000	0.000
mean(diff) $= 0$	0.000	0.000	0.000	0.000
mean(diff) > 0	1.000	1.000	1.000	1.000

Paired t-test on mean differences between overall roll and spot returns for one and two months roll strategies. All values displayed are p-values for the different hypothesis stated.

The second hypothesis tests a mean of zero or negative for the one month roll return when future contracts are rolled forward one month before maturity. Again a distinction is made between base and peak contracts for testing the hypothesis, and as stated before a second test is performed which tests the two months roll return strategy when rolled forward one month before maturity. Test results are split between tables 7 and 8. One month before execution p-value results in table 7 suggest that the tested hypothesis of a mean of zero or negative cannot always be rejected given a 1% confidence interval but always given a 5% confidence interval. Subsequently to this the test indicates that a hypothesis testing for a mean larger than zero cannot be rejected in all four scenario's. However as this is a one-sample t-test the mean value and t-statistic from table 8 have to be taken into account as well. The negative mean roll return in all for scenario's accompanied with negative t-statistics indicate opposite results to the one sample t-test p-value results from table 7. Taking a better look at figures 16 to 19 from the appendix also indicates that in the first month closest to the expiration date of the contract the majority of roll returns appear to be negative. This indication is more clear for two month roll strategies, but rejecting the possibility of a mean of zero or negative is impassable for all four scenario's. Thus the second hypothesis in chapter 3.5 cannot be rejected, and their is no clear indication for a market in backwardation in the month before execution.

The four graphs in the appendix seem to display positive roll returns for the period after the first month before expiration of the contracts instead of during the first month. Tables 7 and 8 therefore also include a second section in which the same test is conducted but for all times to maturity between the first and seventh month. Test results for peak contracts rolled forward one or two months cannot motivate a rejection of a mean equal to zero or positive at the 1% confidence level, only one month roll strategies for peak contracts can be rejected to be positive at the 5% confidence interval. For base contract roll strategies the means are rejected to be zero or positive at the 1% confidence interval in all cases.

But again as with the previous test results the extension of test results and the figures in the appendix seem to show conflicting results on the mean level of the roll return. Opposing table 7 the mean and t-statistic are positive while three out of four cases indicated the impossibility of a positive mean.

Results from the t-test at first appeared to reject the second hypothesis in section 3.5 and therefore indicate a market in backwardation when the forward roll is conducted one month before expiration of the contract. But further outcomes do not support the rejection of a mean roll return equal to zero or negative, therefore the second hypothesis is not rejected. On the contrary it appears as though the period investigated shows a contango market.
Forward rolling the contract before the month the closest to the execution period seems to show similar conflicting results in the tests as when testing the month before execution but with opposing signs. The period before the month closest to execution seems to have a market in backwardation in which contracts rolled forward result in an average positive roll return, opposing the one sample p-value test statistics. A further examination into this changing pattern of roll returns over TLTD is examined with regression 22 in the next section.

Table 7: Grouped T-test on roll returns - p-value results

	1 month roll		2 months roll	
$0 \leq TLTD < 30$	Peak Contracts	Base Contracts	Peak Contracts	Base Contracts
mean < 0	0.003	0.007	0.009	0.006
mean = 0	0.007	0.014	0.017	0.011
mean > 0	0.997	0.993	0.991	0.994

	1 month roll		2 months roll	
$30 \leq TLTD \geq 180$	Peak Contracts	Base Contracts	Peak Contracts	Base Contracts
mean < 0	0.957	1.000	0.933	1.000
mean = 0	0.086	0.000	0.134	0.000
mean > 0	0.043	0.000	0.067	0.000

One-sample close to maturity roll return averages t-test off zero for one and two month roll strategies. All values displayed are p-values for the different hypothesis stated.

Table 8: Grouped T-test on roll returns - other results

$0 \leq TLTD < 30$	**Obs.**	**Mean**	**Std. Err.**	**Std. Dev.**	**t-statistic**	**degr. freedom**
Peak 1m Roll Return	1,094	-0.472	0.175	5.774	-2.707	1,093
Base 1m Roll Return	1,095	-0.377	0.153	5.056	-2.465	1,094
Peak 2m Roll Return	1,095	-0.655	0.274	9.070	-2.388	1,094
Base 2m Roll Return	1,094	-0.391	0.154	5.088	-2.540	1,093

$30 \leq TLTD \geq 180$	**Obs.**	**Mean**	**Std. Err.**	**Std. Dev.**	**t-statistic**	**degr. freedom**
Peak 1m Roll Return	5,392	0.143	0.083	6.167	1.716	5,391
Base 1m Roll Return	5,400	0.481	0.068	4.995	7.078	5,399
Peak 2m Roll Return	5,423	0.200	0.134	9.846	1.499	5,422
Base 2m Roll Return	5,400	0.423	0.068	4.997	6.227	5,399

Extension of results from test results in table 7. Mean, Std. Err. and Std. Dev. stated in percentages.

6.2 Varying risk premia as time to maturity proceeds

Figures 4 and 5 in section 5.2 show the average risk premium per the time to last trading day for both contract types. The figures show that both peak and base contracts have negative risk premia at around -25% as execution of the contract is over 700 days away.

In other words futures prices are about 25% cheaper than the actual average spot price during execution when time to delivery is approximately two years. The discount decreases as the execution period closes and future prices become relatively more expensive. Then for 200 days, between 500 and 300 days before maturity, the slope of the decreasing discount flattens. For peak contracts this period tends to show a mere zero to close to zero increase in the risk premium whilst for base contracts there remains a constant, though lower than before, positive trend. Starting from around 300 days before the last trading day the risk premiums slope increases again and continues to increase on average until the last trading day. For base contracts the risk premium becomes positive approximately 230 days before the last trading day and the majority of risk premia are positive from that point onwards. During this period the average and median risk premium rises to 7% for base contracts, increasing towards 10% in the last month before execution. As positive risk premia occur from a higher futures price than actual average spot price during delivery it indicates a market in contango as the contract has to converge towards the spot price. Which is similar as the indications of the roll return one month before execution. For peak contracts the null line is crossed days before the execution period but keeps fluctuating around zero, with an average of -0.3% in the last month before execution. Thus the risk premium almost always remains negative indicating a backwardated market and a higher actual average spot price than futures contract prices, (slightly) opposing the results from the roll return. Bear in mind that most trades are executed near maturity of the contract, hence the majority of futures prices used are determined from non-executed orders and thus results have to be taken with caution. As time to maturity decreases and execution closes in the relative power in determining the settlement price from traded contracts over non-traded indicative prices does increase as more trades occur. In chapter 5.2 a significant difference is noted in the amount of occurring trades between peak and base contracts. This difference in traded volumes effects the settlement price in a sense that base contracts settlement prices are less influenced by a single trade than peak contract settlement prices. In addition a single trade in a peak contract has a bigger impact on the settlement price as less trades occur and prices jump more. The difference in risk premia very close to maturity might thus originate from the imbalance in liquidity between base and risk contracts.

In order to confirm above findings of changing risk premia over time, as is expected from the explanation of the figures in part 5.2, the risk premium is regressed against the time to last trading day with the following regression. The total results for all peak and all base data is split over the individual execution years.

$$RP_{t,n,T_i} = \alpha_{0,n,T} + \beta_{1,n,T} TLTD + \epsilon_{t,n,T} \tag{22}$$

Inspecting table 9 indicates that all beta's are significant at the 1% level, thus supporting the idea that time to maturity effects the risk premium. The overall peak and base analysis both show in their first column negative beta's, as is graphically displayed in figures 4 and 5. Thus as the time to maturity increases the realized risk premium decreases indicating a discounting affect on the futures contract price over the spot price. With negative overall risk premia found in the previous chapters data analysis the negative risk premium reflects a discount on future over spot prices instead of an actual premium. In the pricing theory this discount would occur when the convenience yield affects of holding the commodity over the futures contract is larger than the costs to store the commodity and the risk free rate over the storage period combined, see equation 4. A decline of an already negative risk premium consequently indicates a larger gap between the future and spot prices, where future contracts are sold cheaper than spot contracts. In reality, opposing to an increasing time to last trading day, time runs in the opposite direction decreasing the time to last trading day.

This shifts tables 9 results such that the realized risk premium increases as time passes, and thus the discount diminishes as maturity nears. The larger estimate for the base contracts beta can be explained from its swift to an average positive risk premium near maturity whilst starting at -25% as peak contracts did. The negative relationship between time to last trading day and the risk premium indicates for an overall backwardation in the market. Table 9 shows the results of beta multiplied with a factor of 100, thus the first columns result represents a daily change in the risk premium of -0.022% for peak contracts. This however still results in a yearly -7.889% change in total. As time to last trading day runs from 0 to 730 days the beta can have severe impact over time.

Table 9: Time to last trading days relationship with the risk premium

	Peak	Peak 2015	Peak 2016	Peak 2017	Peak 2018	Peak 2019
β	-2.162***	1.959***	4.811***	-0.968***	-8.031***	-9.686***
	(9.00e-06)	(6.83e-06)	(1.42e-05)	(1.47e-05)	(1.14e-05)	(2.33e-05)
Constant	-0.010***	0.024***	-0.077***	-0.099***	-0.068***	0.332***
	(0.003)	(0.002)	(0.007)	(0.006)	(0.004)	(0.009)
# obs	25,003	5,165	5,868	6,206	6,212	1,552
R^2	0.022	0.127	0.130	0.007	0.425	0.505

	Base	Base 2015	Base 2016	Base 2017	Base 2018	Base 2019
β	-3.784***	1.389***	3.563***	-2.750***	-9.972***	-11.985***
	(9.34e-06)	(1.00e-05)	(1.12e-05)	(9.97e-06)	(1.27e-05)	(1.68e-05)
Constant	0.109***	0.129***	0.079***	0.019***	0.022***	0.409***
	(0.003)	(0.004)	(0.005)	(0.003)	(0.005)	(0.007)
# obs	25,003	5,165	5,868	6,206	6,212	1,552
R^2	0.063	0.040	0.111	0.109	0.4711	0.746

All β values are multiplied with a factor 100 for readability. Robust standard errors in parentheses, significance at the 1%, 5% and 10% level marked with respectively ***, ** and *. Time series regression analysis testing for variation in the risk premium over time. Split is per execution year of the contract. In example: risk premia used in the analysis for 2015 run between 7-10-2013 up to 27-11-2015 and deliver January to December 2015.

Interestingly when the effects are split out over the individual years of maturity of the contracts, the beta is positive during for first two analyzed years for both peak and base contracts. Here the risk premium showed an opposite trend in which the realized risk premium increased as the execution moment came closer indicating a contango market. This however is mostly attributable to the all time low of futures prices in the Dutch power market as was cited in the 2017 market review of TenneT (2018). An all time low in 2016 reasons towards decreasing average prices during the period upfront and increasing average prices in the period directly afterwards, see also figures 8 to 11. As prices decrease the risk premium is mostly positive as future contracts that execute and establish a spot price were bought relatively expensive before, opposing effects occur when prices increase. This also displays the low predictive power of futures contracts over spot prices. As visible in graphs 8 - 11 the overall low on prices for day-ahead contracts are near the overall low on prices for future contracts. The day ahead lowest prices are on respectively 28-3-2016 and 5-5-2016 for base and peak contracts with the futures contract overall low on 7-4-2016 for both peak and base contracts. This while the different contracts represent the same quantity of power but for different delivery moments in time. The graphed futures contracts average settlement price represents delivery in the period from the remainder of 2016 up to 2018, whilst the day-ahead represents prices for delivery solely on the next day.

Figure 8: Base hours day ahead price

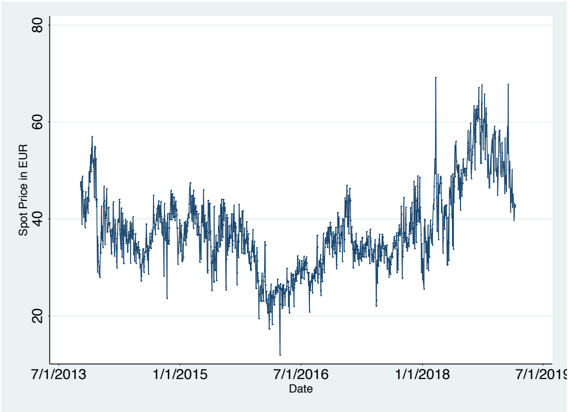


Figure 9: Peak hours day ahead price

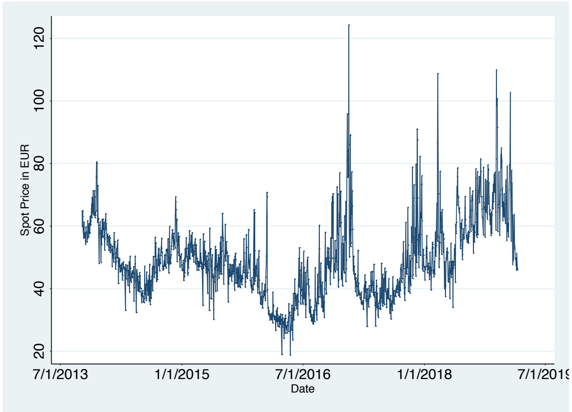


Figure 10: Average settlement price - base contracts

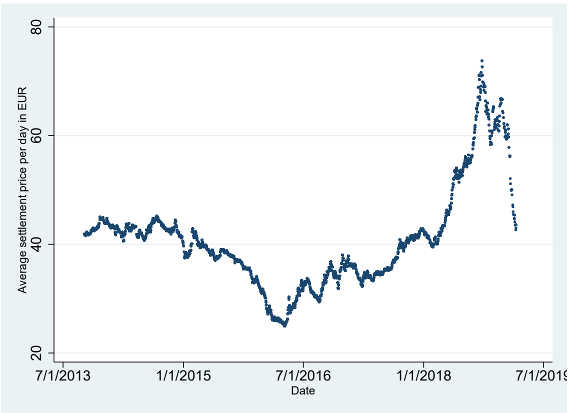
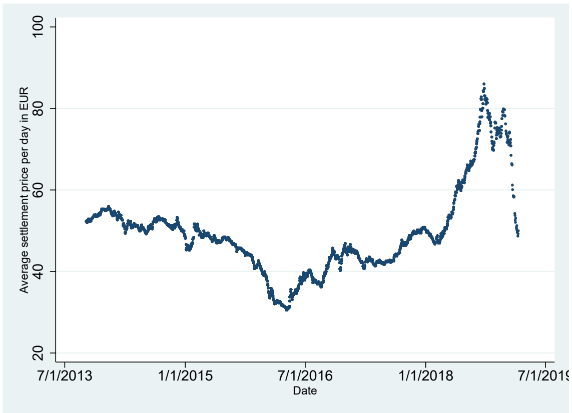


Figure 11: Average settlement price - peak contracts



6.3 Liquidity effect on risk remium

As the risk premium is shown to be varying over time to maturity and between base and peak contracts an affect of liquidity on the risk premium, as mentioned before, could be expected. This relationship is tested with the regression model as shown in equations 12 and 20, for all three liquidity measurements as given in chapter 4.3. Table's 10 correlation matrix provides a look at the correlation between the risk premium and the three liquidity variables: (Il)liquidity, open interest and the standard deviation of the logarithmic return. The correlation between the risk premium and Amihud's (Il)liquidity measure and Std. dev. are negative for both peak and base contracts whilst the correlation between the risk premium and open interest is positive. This shows consistency through difference between the risk premium and illiquidity and liquidity measurements. The correlation with the standard deviation and the risk premium is the strongest, which is partly expected from the similarity in construction of risk premia and standard deviation from the futures prices. However this is also the case for Amihud's (Il)liquidity which does not correlate much with the risk premium. Striking out is the reversed correlation between open interest and Amihud's (Il)liquidity measurement as it shifts from a positive relationship in peak contracts towards a negative relationship for base contracts. A similar shift but from opposing signs occurs between the base and peak correlation of the standard deviation and the open interest.

Table 10: Correlation matrices for the risk premium and liquidity variables

Peak	Risk Premium	(Il)liquidity	Open Interest	Std. dev.
Risk Premium	1.000			
(Il)liquidity	-0.077	1.000		
Open Interest	0.061	0.006	1.000	
Std. dev.	- 0.171	-0.086	-0.088	1.000

Base	Risk Premium	(Il)liquidity	Open Interest	Std. dev.
Risk Premium	1.000			
(Il)liquidity	-0.098	1.000		
Open Interest	0.023	-0.017	1.000	
Std. dev.	- 0.272	-0.087	0.129	1.000

Results from the Hausman test in table 16 of the appendix indicate rejection of the null hypothesis of a random effects model as appropriate for (Il)liquidity and Std. dev. Use of a fixed effects model for (Il)liquidity and standard deviation thus is viable but a random effects model is used for the open interest standard. Table 11 shows the results, which are low in explanatory value as is observable from the power of R^2, but are highly significant on the beta in all cases at the 1% level. Despite the low explanatory power the analysis shows that market liquidity does influence the dependent variable risk premium. Consistent with the correlation matrix (Il)liquidity and standard deviation show negative relationships with the risk premium whilst the open interest has a positive relationship.

As markets become less liquid the (Il)liquidity measurement of Amihud rises and corresponding the risk premium declines. One has to bear in mind that the risk premium is negative in the majority of cases, as indicated in parts 5.2 and 6.2, and resembles a discount on the spot price. A negative relationship between Amihud's (Il)liquidity measurement and the risk premium thus indicates that the higher the illiquidity in the market the bigger the discount in future prices over spot prices.
The third and sixth column on open interest indicate that a market with more open contracts results in a higher risk premium, and therefore a smaller discount. With the coefficient in the 1000th of a point the effects seem small but open interest is shown throughout the data to be high for a majority of moments and has relatively large amplitudes in the minimum and maximum values. More open interest is predominantly seen as more liquidity in the market thus decreasing the discount as liquidity rises. This is in line with the relationship between risk premia and Amihud's (Il)liquidity measure as open interest measures liquidity instead of illiquidity. However more open interest in a market has also been argued to indicate the lack of liquidity as was stated before, thus results have to be made with caution.
For the standard deviation of the logarithmic return the estimated beta is negative in both cases indicating that the higher the standard deviation is the lower the risk premium becomes. A higher standard deviation occurs as the market becomes less liquid and a single trade has a bigger impact on the futures price. The increased standard deviation results in a lower beta and thus a bigger discount on the futures price similar to the effects of Amihud's (Il)liquidity measurement. A more liquid market in which the amplitudes of price volatility can be expected to be lower has less standard deviation in the return on future prices and therefore has a smaller discount in the risk premium on the futures contract price.

The causal affect is affirmed with a Granger Causality test between the risk premium and open interest and std. dev. Due to a lack of balance in the data the test could not be performed for Amhiud's (Il)liquidity measure.

A rejection of the tested null hypothesis of no causal relationship indicates a causal relationship. For open interest this was possible with a 5% significance at the 2nd order lag and a 1% significance at the first lag, whilst for base contracts this was only possible for the first lag with a 1% significance. When testing the standard deviation in peak contracts data the null could be rejected for the 2nd order lag with 1% significance, and at the 1st order lag with 1% significance for base contracts. Complete results can be found in the appendix table 17.

Table 11: Relationship between liquidity measurements and the risk premium

	Peak			**Base**		
	(Il)liquidity	Open Interest [1]	Std. dev.	(Il)liquidity	Open Interest [2]	Std. dev.
β	-3.921***	2.54e-04***	-0.095***	-4.464***	1.30e-04***	-0.086***
	(1.223)	(8.19e-06)	(0.003)	(1.073)	(1.30e-04)	(0.003)
Constant	-0.095***	-0.166***	-0.003***	-0.064***	-0.153***	0.055***
	(0.004)	(0.035)	(0.004)	(0.003)	(0.036)	(0.004)
# obs	2,350	24,919	23,749	4,462	24,919	23,749
R^2	0.013	0.037	0.032	0.016	0.074	0.027

Robust standard errors in parentheses, significance at the 1%, 5% and 10% level marked with respectively ***, ** and *. All analysis have 51 groups, equivalent to the amount of unique contracts for peak and base delivery. The fixed effects within OLS analysis is performed except for the open interest liquidity measurement (1 & 2) which is run with a random effects model in accordance with the results of the Hausman test, table 16 in the appendix.

Results from table 11 oppose those expected in hypothesis 4,5,6 and 7. But the results are in line with the given explanation that an increase in market liquidity decreases the difference between the futures and spot price as liquidity in the market provides security to the futures value. However since the risk premium is a discount instead of a premium on top of the spot price the relationships are opposing the expected relationships. The results are consistent as they change sign with the use of a liquidity versus illiquidity measure.

6.4 Extended model for the liquidity effect

With known directions for the relationship between liquidity and risk premia as shown in table 11 the possibility to trade accordingly becomes present. However as was also shown in the same table the predictive power of the different models is, despite significant, low due to the high degree of independent variables situated in the error terms. Bevin-McCrimmon et al. (2018) showed that the underlying fuel prices, a load factor and spot price characteristics influence the risk premia. Continuing on this model equation 21 is formed and tested to provide a start in the analysis of the risk premium for further research and to see whether liquidity remains to hold explanatory power as differing variables are added to the model.
P-value statistics in table 12 show the results of testing the extended risk premium model for diagnostic characteristics within the data. The White test on heteroskedasticity across time, with null hypothesis of homoskedasticity, rejects the null hypothesis. This occurs with all three variables for both peak and base contracts, thus the extended regression should correct for heteroskedasticity. Pesaran's cross sectional dependence check also results in a rejection of the tested null hypothesis for cross section independence on the open interest and standard deviation variable. The test could however not be performed for the (Il)liquidity measurement as there are not enough overlapping cross section observations on the same dates. The rejection of cross section independence indicates for contemporaneous correlation and thus limits the variance estimate if not accounted for, however this does not bias the estimated coefficients. All liquidity variables show for peak and base contracts serial correlation when running a pooled regression against the explanatory variables and the prior period's residual.

The Wooldrige test performs a t-test on the coefficient of past residuals using heteroskedastic robust standard errors. The null hypothesis of no serial correlation is strongly rejected in all examined cases and thus also has to be corrected for in the regression analysis. Lastly Fishers unit roots test, based on the augmented Dickey-Fuller test statistics, shows a rejection of the null hypothesis from the second order lag. The modified inverse p-value is shown in table 12 as rejection. Rejecting the null hypothesis shows that in at least one panel stationarity is present and not all panels contain unit roots. Complete test results can be found in tables 18 to 21 in the appendix.

Table 12: Diagnostic test statistics

	Peak	(Il)liquidity	Open Interest	Std. dev.
Heteroskedasticity White Test				
$H_0 : \sigma_{n,T} = \sigma$		0.000	0.000	0.000
Contemporaneous Correlation Pesaran Test				
$H_0 : \sigma_{n,T} = 0$		#N/A	0.000	0.000
Serial Correlation Wooldrige Test				
$H_0 : \rho = 0$		0.000	0.000	0.000
Stationarity Fisher Test				
$H_0 : \rho_{n,T} = 1$	0.000			

	Base	Open Interest	(Il)liquidity	Std. dev.
Heteroskedasticity White Test				
$H_0 : \sigma_{n,T} = \sigma$		0.000	0.000	0.000
Contemporaneous Correlation Pesaran Test				
$H_0 : \sigma_{n,T} = 0$		#N/A	0.000	0.000
Serial Correlation Wooldrige Test				
$H_0 : \rho = 0$		0.000	0.000	0.000
Stationarity Fisher Test				
$H_0 : \rho_{n,T} = 1$	0.000			

Results in P-values, Fisher test in modified inverse p-value

To correct for the diagnostic test results two different regression models are looked at which are both adjusted ordinary least squares. The panel correction standard errors (PCSE) OLS corrects for heteroskedasticity, contemporaneous and serial correlation with inclusion of the first lagged dependent to hold for stationarity. However as the examined data has 51 different groups resembling the individual contracts, the regression can induce stronger than actual relationships with such high number of groups. Therefore the second model is performed on the same regression (equation 21) but with a variance-covariance matrix corresponding to the parameter estimates and robust standard errors. Table 13 shows the summarized results for the first order lagged regression run with the variance-covariance robust estimates and the three different measurements for liquidity split between peak and base contracts. Complete test results with a variaty of lagged dependends included can be found in the appendix tables 22, 23 and 24. Similarly the summarized and complete test results for the panel corrected standard errors (PCSE) models can be found in tables 25 to 28.

Table 13: Extended model on relationship between liquidity measurements and the risk premium

VARIABLES	Peak			Base		
Constant	-0.047**	-0.022*	-0.025*	-0.013	-0.012	-0.012
	(0.024)	(0.013)	(0.015)	(0.014)	(0.009)	(0.009)
(Il)liquidity	-3.807***			-3.777***		
	(0.435)			(0.250)		
Open Interest		-7.49e-06**			7.36e-07*	
		(3.19e-06)			(4.09e-07)	
Standard Deviation			-8.87e-04			-8.05e-04***
			(0.001)			(2.93e-04)
Skewness	-0.002*	-0.001***	-6.01e-04**	-5.88e-04	3.45e-04**	3.06e-04*
	(0.001)	(3.43e-04)	(3.02e-04)	(5.20e-04)	(1.60e-04)	(1.61e-04)
Variance	8.90e-06	-2.92e-05***	-3.76e-05***	-1.43e-04***	-3.82e-05	-5.52e-05
	(1.90e-05)	(8.18e-06)	(8.85e-06)	(5.38e-05)	(5.47e-05)	(5.76e-05)
Spot Price	9.40e-04***	7.90e-04***	8.69e-04***	4.09e-04**	3.32e-04	4.12e-04*
	(2.37e-04)	(1.90e-04)	(1.86e-04)	(2.01e-04)	(2.07e-04)	(2.20e-04)
Carbon Allowances	0.018*	-0.003	-0.008***	-0.010***	-0.002*	-0.003**
	(0.009)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
Gas	-0.095***	-0.051***	-0.056***	-0.046**	-0.015	-0.018*
	(0.024)	(0.014)	(0.014)	(0.020)	(0.011)	(0.011)
Oil	-0.011	-0.016***	-0.011***	0.006	-0.025***	-0.023***
	(0.018)	(0.003)	(0.003)	(0.009)	(0.002)	(0.002)
Coal	0.072***	-0.005	-0.006	-0.002	-0.009	-0.009
	(0.023)	(0.007)	(0.008)	(0.009)	(0.006)	(0.006)
Load	-2.43e-07	-1.27e-06	-1.50e-06	-8.68e-08	-1.21e-07	-1.41e-07
	(1.78e-06)	(1.09e-06)	(1.25e-06)	(8.25e-07)	(4.56e-07)	(4.94e-07)
1st lag RP	0.971***	0.980***	0.979***	0.991***	0.995***	0.995***
	(0.008)	(0.004)	(0.004)	(0.004)	(0.001)	(0.001)
Observations	1,954	23,643	22,472	3,707	23,640	22,470
R^2	0.972	0.978	0.977	0.988	0.987	0.986
Number of contractID	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***, ** and *. Variance covariance estimator (VCE) robust regression estimates on risk premium with the first lagged dependent variable included. Distinction between peak and base contracts and three different measurements for liquidity in the market: (Il)liquidity, open interest and standard deviation.

Amihud's (Il)liquidity measures coefficient is highly significant for both peak and base contracts, and both coefficients are likely in the earlier model possessing a negative sign. This corresponds with the before mentioned relationship in which less liquidity, resulting in a higher level of (Il)liquidity, decreases the risk premium and thus increases the discount on future prices over spot prices. As future contract value becomes less secure in the illiquid market, the holder of the future demands a bigger discount over the spot price.

Interestingly the sign before the coefficient of the open interest measurement has shifted for peak contracts towards a negative relationship over the earlier found positive relationship, and is significant at the 5% level. This would indicates that contradicting to all other findings liquidity does not decrease the discount on future peak contracts. Looking at table 23 in the appendix the negative coefficient occurs as soon as the lagged value of the dependent variable is included in the model. This could indicate that the explanatory power of open interest on liquidity diminishes as a previous time period is included in the model, in line with this it is known that the open interest observations fluctuations per day are limited. However in contrast it can also indicate that as one knows the risk premium of yesterday the effect of liquidity in the market offsets the lower discount.

This might occur due to a known opposite direction of open interest on liquidity in the market, in other words it could be that a higher open interest is interpreted by market participants as less instead of more liquidity due to the imbalance in long versus short parties. However this can only be speculated upon at this point, and future research will have to address this issue more in depth. For future base contracts the direction of the relationship between the risk premium and markets liquidity remains positive as in the earlier tested model, the significance however decreased.
Using the standard deviation measurement for illiquidity in the market displays similar results as earlier but only significant in the base contracts risk premium analysis. As in table 11 the relationship with the risk premium is negative which indicates that a more illiquid market results in a higher discount on the futures price over the actual realized spot price for electricity.

The effect of increased skewness of the spot price on peak contracts risk premium is constantly negative and significant, but for base contracts this changes depending on the liquidity measurement. Significant (although low) results show positive correlation with the risk premium from the skewness. A more abnormal distribution of spot prices thus reflects towards a bigger discount on future prices for peak contracts, but a lower discount for base contracts. The variance of the spot price, for all significant coefficients, indicates a negative correlation with the risk premium. Thus increased spot price fluctuation of the realized spot return in the execution month increases the discount on the future contract prices over the spot price. The spot price self shows a positive correlation with the risk premium in all scenarios, though not always significant. Higher spot prices thus reduce the discount of future prices.
Price changes in future contracts on Carbon Allowances, Gas, Oil and Coal have significant effect on the risk premium respectively three, four, four and one out of six models. The effects from gas and oil, when significant, are negative and thus indicate that an increasing price changes of future contracts for an underlying fuel lowers the risk premium and hence increases the discount on future prices. For carbon allowance future prices the relationship is mostly negative but the one significant coefficient for coal is positive indicating opposing affects.
The load factor which should account for seasonality is insignificant in all models. Whilst the first order lag of risk premium is significant at the 1% level in all tested models. The latter is in all cases highly indicative for this periods risk premium which is as expected as the risk premiums change occurs from daily settlement price changes which are on average low. The constant is somewhat significant for the tested models on peak contract and non whatsoever for base contracts.

7 Conclusion

In this research the electricity future contract prices in the Dutch electricity market are examined. As electricity cannot be stored it is shown in earlier research that electricity contract prices contain a positive risk premium opposing other energy commodities such as oil and gas which can be stored. However as maturity nears for a contract demand volatility lowers whilst capacity risks for trading parties remain the same. Meanwhile liquidity in the market is expected to increase as hedgers try to roll forward their current positions close to the last possible trading day. Therefore it is argued that electricity futures contracts should show similar price behaviour near maturity as difficult to store commodities do. Rising futures prices near maturity will result in positive roll returns indicating markets in backwardation and negative risk premia. Thus the following research question is examined:

Are electricity futures contract markets in backwardation as maturity of the contracts closes in?

7.1 Hypothesis results

Three hypothesis are tested for: the presence of a risk premium, a positive roll return one month before maturity and a positive relationship between the risk premium and illiquidity in the market. For the last hypothesis three indicating variables are used, Amihud's (Il)liquidity measure and the standard deviation of the logarithmic return as illiquidity measures and open interest as a liquidity measure. The hypothesis are tested with a data set composed of the ICE exchange with contracts maturing between January 2015 and March 2019. Testing the mean difference between roll and spot returns indicated inequality of the mean difference from zero for both peak and base contracts and the two roll strategies one and two months forward. The presence of a risk premium in the Dutch futures power market can therefore be acknowledged as was expected.

Looking at the mean roll return when rolling forward of the contract, either peak or base, is performed one month before execution it cannot be determined to be positive. In contrary it is more likely that the average roll return one month before execution is negative and thus indicates towards a normal futures curve instead of an inverted one. This seems to be the strongest in the case of peak contracts when rolled forward two months ahead in execution. Roll returns when the rolling forward occurs before the last trading month are on average positive. Results from these tests thus partly counter the expectations of the author as they indicate that a futures contract near maturity is more expensive than one further away from execution, but not in the last month before execution. Attributed risks do seem to be higher as execution closes in without storage possibilities but longer to maturity futures are more valuable alternatives than spot contracts. Most of all, this result however challenges the link between a negative risk premium with backwardation and a positive roll return which is contradicted by the analysis of peak contracts but affirmed through analyzing base contracts.

The actual realized risk premium of the settlement prices as given in the ex post expectations theory is shown to be negative throughout the majority of the data set during the two years ahead of delivery, for both peak and base contracts. Two years before maturity the risk premiums start around -25% signaling that a significant discount applies for future contracts long before maturity. The convenience yield of holding electricity over a futures contract therefore is significant indicating low applicability of a futures contract as a replacement for storage. However the discount diminishes along with the time to maturity.

For peak contracts the discount on future prices is around zero near maturity of the contract and remains negative on average, but for base contracts this risk premium at maturity has turned positive from approximately 200 days before maturity averaging at a 10% premium the last month before execution. As expected the time to maturity is shown to be a significant influencing factor for the risk premium of futures contract prices with holding a negative relationship. This indicates that as the time to maturity increases the risk premium decreases along and the discount given on future contracts increases. But as time to maturity decreases in reality the discount diminishes along with it.

In contrast to the expected effects, the affects of illiquidity on the risk premia are shown to be negative and thus decreasing instead of increasing the risk premium as the market turns less liquid. However as the risk premium is shown to be a discount instead of a premium the difference between future and spot prices increases as illiquidity in the market rises and decreases as illiquidity lowers as was expected. All three tested liquidity variables indicate this similar result for both peak and base contracts. This indicates that the holders of future contracts demand a larger discount on prices as the security of the value of the future decreases along with increased illiquidity. The relationships are all shown significant at the 1% level but the tested models have weak explanatory power as no other variables are included.
The tested extended model has a large explanatory power but shows varying significance in their results. For the one lagged models tested with the three liquidity variables the correlation between risk premia and illiquidity does remain constant with previous findings except for the open interest measure when testing on peak contracts. In this model the sign before the coefficient shifted from positive towards negative which could indicate that open interest in peak contracts isn't measuring liquidity but illiquidity or that liquidity in the market does not decrease but enlarge the discount given on futures contracts. However overall the extended model results confirm those of the simple model.

7.2 Limitations and recommendations

This research finds limitations in its construction through several aspects. First of all the used dataset limits at 4 years and 2 months of maturity which is more than most literature but still limited. During this period, as was indicated by TenneT (2018), the lowest overall price for futures contracts was reached in 2016. This influences the risk premia and roll returns significantly. Secondly the liquidity variable Amihud's (Il)liquidity measure did not have a sufficient amount of observations over the dataset compared to the other variables to accept the findings on the same level as those from the other variables. Lastly the used regression models are limited in estimating the coefficients relative strength or power on the risk premium, but merely indicate the way of the relationship.
Further research on electricity future contracts could look into the effects of adding an analysis on financially settled futures contracts over physically settled contracts as this might increase presence of hedgers in the market. Also the extended regression models should be improved with better variables replacing those that are insignificant and adding others which could be significant.
As the northwest European power market integrates ever more it would also be interesting to look at similar effects outside the Dutch electricity market. The effect from liquidity on the risk premium can be expected to remain positive in other regions but further research will have to approve this. Besides this the influencing factor from purely renewable fuels, and thus making production of electricity completely impossible to store, on the effects of liquidity in the futures market is interesting.

Overall this research showed that despite previous literature indicating towards positive risk premia for electricity futures markets the actually realized risk premia in the Dutch futures electricity market is negative. This indicates a backwardated market situation where holding the commodity is preferred, despite storage possibilities, over holding the right on the commodity of the future. A discount is thus given on the futures price as time to maturity is far away. When time to maturity closes in the discount does however diminish and a difference becomes visible between peak and base contracts. Peak contracts average risk premium remains slightly negative from zero until maturity, whilst base contracts risk premia start to turn positive 200 days before execution ending in an average 10% premium in the month before execution. This difference is found to be partly correlated with the liquidity or illiquidity in the market. A negative relationship is found between illiquidity in the market and the risk premium, signaling an increase in discount as illiquidity rises.
This indicates that holding the contract longer on average increases its relative value towards the spot price and futures with a longer time to maturity, but only up to a point when holding it further diminishes value compared to holding next months future. And that it cannot be concluded that electricity future markets in the Netherlands are in backwardation near maturity.

8 Appendix

Table 14: Variable definitions

Variable	**Definition**	**Source**
Risk Premium ($RP_{t,T}$)	Ex-post risk premium: difference between the daily futures contract settlement price and the average day-ahead price during delivery over the average day-ahead price during the delivery month	own calculations
Volume	Daily trading volume of the Dutch base and peak futures contracts traded on the ICE Endex exchange	Ice Endex Data
(Il)liquidity	Amihud's (Il)liquidity measure as in equation 17: the ratio of return on settlement price over prior days price and the traded volume	own calculations
Open Interest	Number of unsettled (open) futures contracts in the market	Bloomberg
Standard Deviation of the Logarithmic Return	Standard deviation of the logarithmic return of the settlement price of t over $t-1$ over previous 60 days average, continuously rolled forward	own calculations
Skewness (SkewS_n)	Skewness of day-ahead price over the previous 60 working days, continuously rolled forward	own calculations
Variance (VarS_n)	Variance of day-ahead price over the previous 60 working days, continuously rolled forward	own calculations
SpotPrice (S_n)	Previous days closing price for day-ahead delivery of a MWh electricity traded on the APX power market in EURO	Bloomberg
Carbon Allowances ($Carbon_t$)	Natural logarithmic return of the generic 1st month EUA Carbon Emission futures contract against the past rolled over 30 working days	Bloomberg
Oil (Oil_t)	Natural logarithmic return of the generic 1st month European Crude Dated Brent Spot futures contract against the past rolled over 30 working days, delivery settled contract unless requested to settle financially	Bloomberg
Gas (Gas_t)	Natural logarithmic return of the generic 1st month ICE Endex TTF Natural Gas futures contract against the past rolled over 30 working days, delivery settled at the TTF point	Bloomberg
Coal ($Coal_t$)	Natural logarithmic return of the generic 1st month ARA Coal futures contract against the past rolled over 30 working days, financially settled against the price of coal delivered into the Amsterdam, Rotterdam and Antwerp region in the API 2 Index	Bloomberg
Load ($Load_T$)	Supplied electricity in the Netherlands during the delivery period of the contract in MWh	International Energy Agency

Figure 12: One month roll-return over date

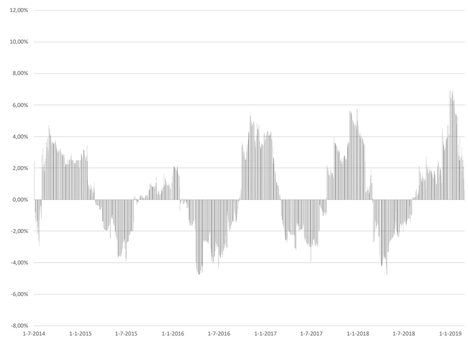


Figure 13: Two months roll-return over date

Figure 14: One-month roll return histogram

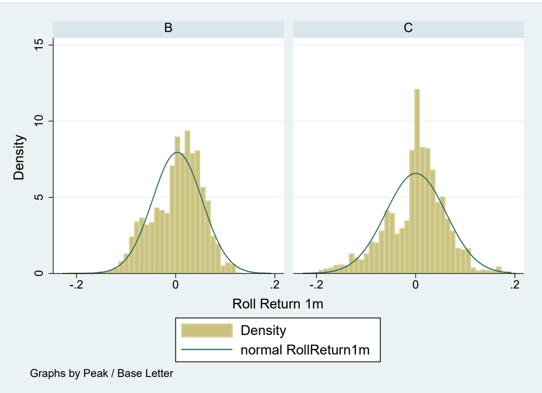
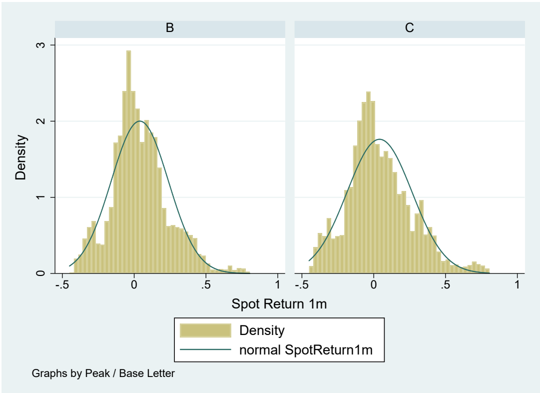


Figure 15: One-month spot return histogram



B graphs for Base contracts, C graphs for Peak contracts

Figure 16: One month roll return over TLTD - base contracts

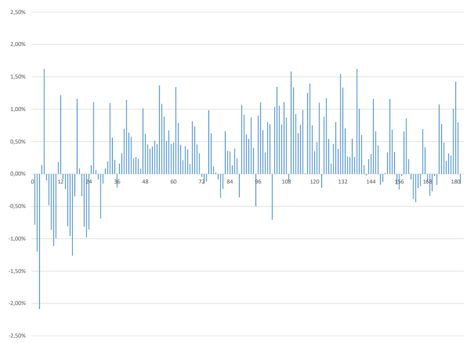


Figure 17: One month roll return over TLTD - peak contracts

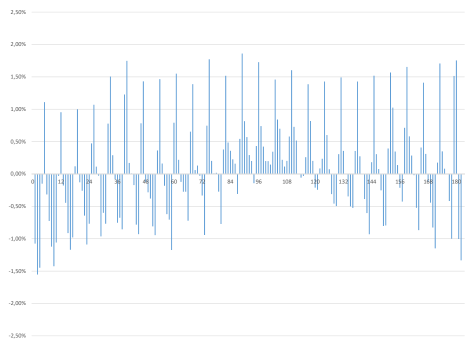


Figure 18: Two months roll return over TLTD - base contracts

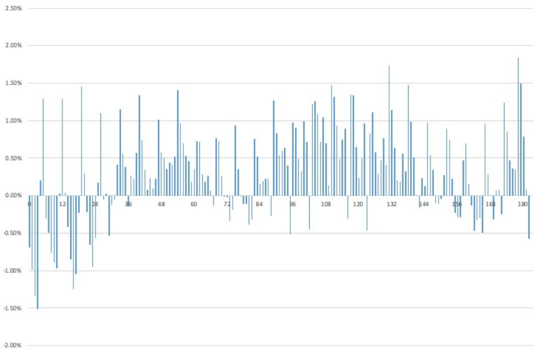


Figure 19: Two months roll return over TLTD - peak contracts

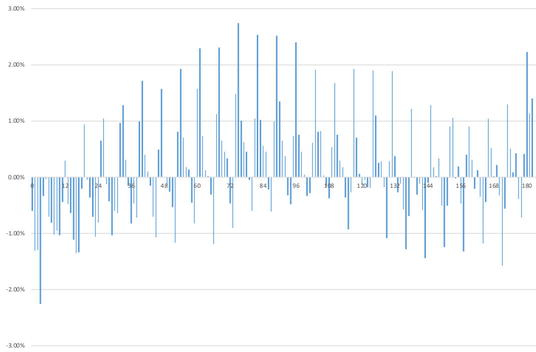


Figure 20: Average settlement price over TLTD - base contracts

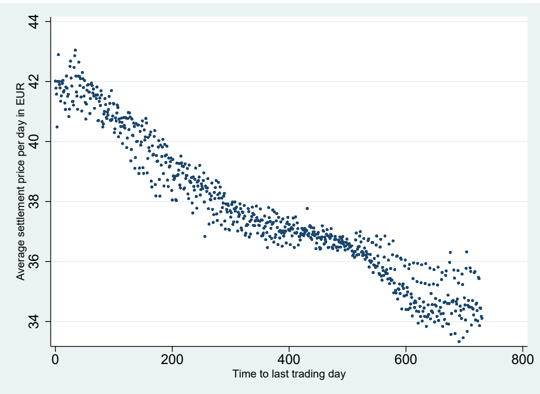


Figure 21: Average settlement price over TLTD - peak contracts

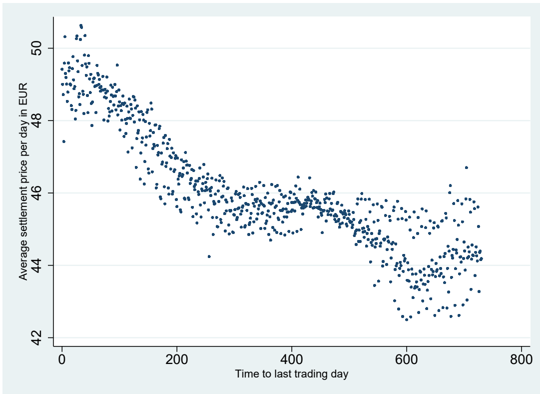


Table 15: T-test results on roll and spot returns

Peak	**Obs.**	**Mean**	**Std. Err.**	**Std. Dev.**	**t**	**degr. freedom**
1m Roll Return	6,486	0.039	0.075	6.072	-11.173	6,485
1m Spot Return	6,486	3.546	0.268	21.560	-11.173	6,485
2m Roll Return	6,518	0.057	0.120	9.724	-10.365	6,517
2m Spot Return	6,518	4.360	0.327	26.361	-10.365	6,517
Base	**Obs.**	**Mean**	**Std. Err.**	**Std. Dev.**	**t**	**degr. freedom**
1m Roll Return	6,495	0.336	0.062	5.015	-12.924	6,494
1m Spot Return	6,495	3.929	0.247	19.942	-12.924	6,494
2m Roll Return	6,494	0.286	0.062	5.021	-13.561	6,493
2m Spot Return	6,494	4.683	0.296	23.831	-13.561	6,493

Extended test results on test in table 6. Mean, Std. Err. and Std. Dev. in percentages.

Table 16: Hausman-test results

Peak	FE	RE	Difference	S.E.	χ^2	p-value
(Il)liqudity	-3.920	-4.019	0.100	0.037	7.29	0.007
Open Interest	2.54e-04	2.54e-04	2.24e-07	2.32e-07	1.02	0.314
Std. Dev.	-0.095	-0.095	9.02e-04	3.70e-04	15.92	0.000

Base	FE	RE	Difference	S.E.	χ^2	p-value
(Il)liqudity	-4.464	-4.532	0.069	0.022	9.32	0.002
Open Interest	1.30e-04	1.30e-04	1.37e-07	4.65e-08	1.23	0.267
Std. Dev.	-0.086	-0.087	3.37e-04	5.37e-04	39.28	0.000

Simple risk premium regression test results for liquidity variables

Table 17: Granger Causality test results

	Peak			Base		
	(Il)liquidity	Open Interest	Std. Dev.	(Il)liquidity	Open Interest	Std. Dev.
1st order lag	#N/A	0.000	0.000	#N/A	0.001	0.008
2nd order lag	#N/A	0.047	0.000	#N/A	0.556	0.746
3rd order lag	#N/A	0.751	0.829	#N/A	0.001	0.841

P-values of Z-bar from Dumitrescu & Hurlin Granger non-causality test results.

Figure 22: Average risk premium over illiquidity - base contracts

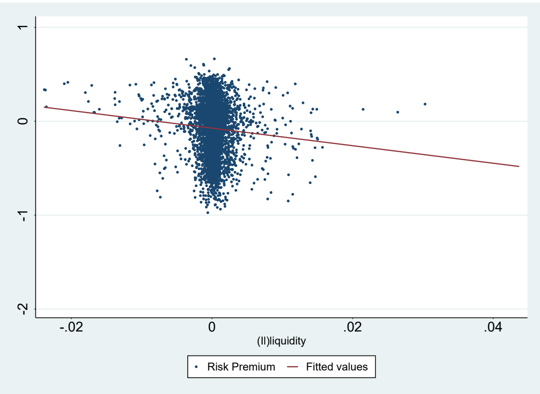


Figure 23: Average risk premium over illiquidity - peak contracts

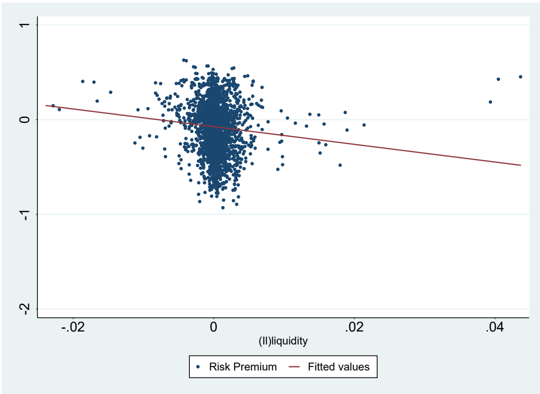


Figure 24: Average risk premium over open interest - base contracts

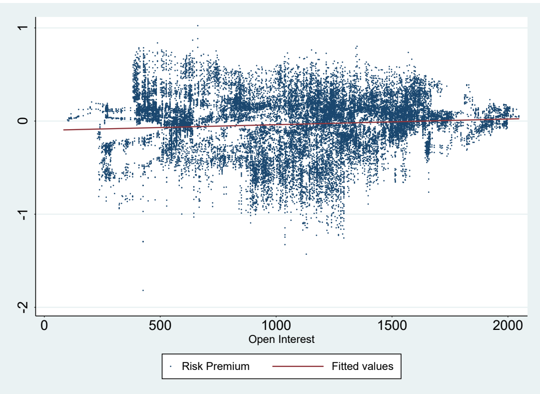


Figure 25: Average risk premium over open interest - peak contracts

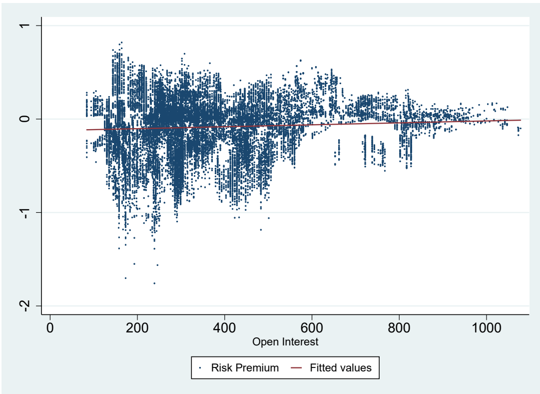


Figure 26: Average risk premium over standard deviation - base contracts

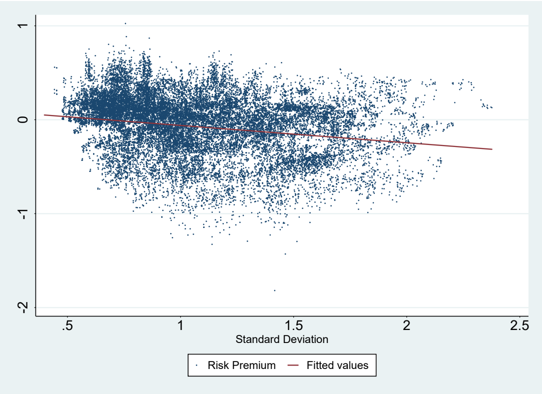


Figure 27: Average risk premium over standard deviation - peak contracts

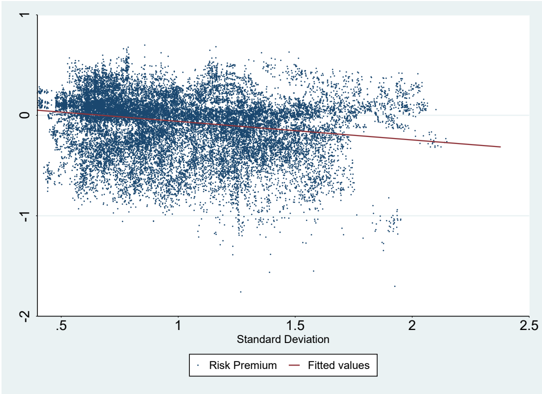


Table 18: White test results

	Peak			**Base**		
	(Il)liquidity	Open Interest	Std. Dev.	(Il)liquidity	Open Interest	Std. Dev.
χ^2	1,223.21	15,019.93	15,281.52	2,812.76	16,326.74	14,008.45
prob $> \chi^2$	0.000	0.000	0.000	0.000	0.000	0.000

Table 19: Pesaran test results

	Peak			**Base**		
	(Il)liquidity	Open Interest	Std. Dev.	(Il)liquidity	Open Interest	Std. Dev.
CD-test	#N/A	533.97	20.15	#N/A	476.00	18.89
p-value	#N/A	0.000	0.000	#N/A	0.000	0.000
corr	#N/A	0.838	0.036	#N/A	0.752	0.033
abs(corr)	#N/A	0.838	0.369	#N/A	0.756	0.339
# groups	#N/A	51	51	#N/A	51	51

Table 20: Wooldridge test results

	Peak			**Base**		
	(Il)liquidity	Open Interest	Std. Dev.	(Il)liquidity	Open Interest	Std. Dev.
F-statistic	302.58	1,508.31	1,449.53	403.68	329.87	334.36
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Table 21: Fishers test results

	Peak			**Base**		
	1 lag	2 lags	3 lags	1 lag	2 lags	3 lags
Modified inverse χ^2 statistic	21.192	16.266	5.809	9.790	5.454	0.114
Modified inverse χ^2 p-value	0.000	0.000	0.000	0.000	0.000	0.455
# panels	51	51	51	51	51	51
Average # observations	490.25	490.25	490.25	490.25	490.25	490.25

Table 22: VCE(robust) regression estimator with (Il)liquidity

VARIABLES	Peak	Peak 1L	Peak 2L	Peak 3L	Base	Base 1L	Base 2L	Base 3L
Constant	-0.337	-0.047**	-0.047**	-0.039*	-1.010**	-0.013	-0.009	-0.007
	(0.371)	(0.024)	(0.024)	(0.023)	(0.489)	(0.014)	(0.013)	(0.013)
(Il)liquidity	-2.268**	-3.807***	-3.788***	-3.707***	-2.179***	-3.777***	-3.877***	-3.807***
	(0.888)	(0.435)	(0.450)	(0.483)	(0.597)	(0.250)	(0.267)	(0.252)
Skewness	-0.033**	-0.002*	-0.002*	-0.002	0.026***	-5.88e-04	-1.07e-04	-7.73e-05
	(0.013)	(0.001)	(0.001)	(0.001)	(0.005)	(5.20e-04)	(6.59e-04)	(6.66e-04)
Variance	7.51e-04***	8.90e-06	5.09e-06	-1.48e-05	0.002***	-1.43e-04***	-1.55e-04**	-1.64e-04**
	(1.59e-04)	(1.90e-05)	(1.88e-05)	(2.07e-05)	(3.94e-04)	(5.38e-05)	(6.31e-05)	(6.75e-05)
Spot Price	0.009***	9.40e-04***	9.47e-04***	9.83e-04***	0.018***	4.09e-04**	4.19e-04**	4.13e-04*
	(0.001)	(2.37e-04)	(2.51e-04)	(2.6e-04)	(0.002)	(2.01e-04)	(2.13e-04)	(2.17e-04)
Carbon Allowances	0.033	0.018*	0.009	0.018*	-0.075*	-0.010***	-0.007**	-0.007**
	(0.046)	(0.009)	(0.009)	(0.010)	(0.040)	(0.003)	(0.003)	(0.003)
Gas	0.126	-0.095***	-0.093***	-0.120***	-0.136	-0.046**	-0.053**	-0.058**
	(0.111)	(0.024)	(0.024)	(0.026)	(0.083)	(0.020)	(0.022)	(0.023)
Oil	-0.210***	-0.011	-0.018	0.004	-0.206**	0.006	0.008	0.011
	(0.068)	(0.018)	(0.019)	(0.018)	(0.084)	(0.009)	(0.009)	(0.010)
Coal	0.473***	0.072***	0.077***	0.070***	0.685***	-0.002	-0.002	-0.002
	(0.134)	(0.023)	(0.022)	(0.020)	(0.082)	(0.009)	(0.008)	(0.008)
Load	-1.96e-05	-2.43e-07	-1.95e-07	-1.03e-06	3.80e-05	-8.68e-08	-3.88e-07	-5.70e-07
	(3.84e-05)	(1.78e-06)	(1.74e-06)	(1.56e-06)	(4.88e-05)	(8.25e-07)	(7.50e-07)	(7.05e-07)
1st lag RP		0.971***	0.731***	0.623***		0.991***	0.853***	0.837***
		(0.008)	(0.028)	(0.031)		(0.004)	(0.027)	(0.031)
2nd lag RP			0.244***	-0.019			0.139***	0.038***
			(0.026)	(0.028)			(0.025)	(0.012)
3rd lag RP				0.380***				0.119***
				(0.028)				(0.020)
Observations	1,978	1,954	1,914	1,893	3,752	3,707	3,657	3,605
R^2	0.120	0.972	0.972	0.977	0.093	0.988	0.988	0.989
Number of contractID	49	49	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***,** and *. Variance covariance estimator (VCE) robust regression estimates on risk premium with the (Il)liquidity variable over peak and base contracts with differing lagged periods.

Table 23: VCE(robust) regression estimator with open interest

VARIABLES	Peak	Peak 1L	Peak 2L	Peak 3L	Base	Base 1L	Base 2L	Base 3L
Constant	0.126	-0.022*	-0.026**	-0.027**	-0.799	-0.012	-0.012	-0.011
	(0.452)	(0.013)	(0.013)	(0.013)	(0.564)	(0.009)	(0.009)	(0.009)
Open Interest	1.82e-04**	-7.49e-06**	-8.62e-06**	-8.89e-06**	9.58e-05***	7.36e-07*	8.11e-07**	1.16e-06***
	(8.62e-05)	(3.19e-06)	(3.57e-06)	(3.75e-06)	(2.23e-05)	(4.09e-07)	(4.01e-07)	(4.04e-07)
Skewness	-0.049***	-0.001***	-0.001	-0.001	0.012***	3.45e-04**	4.26e-04**	3.04e-04
	(0.005)	(3.43e-04)	(3.86e-04)	(3.84e-04)	(0.004)	(1.60e-04)	(1.99e-04)	(2.06e-04)
Variance	2.61e-04***	-2.92e-05***	-2.83e-05***	-2.92e-05***	0.002***	-3.82e-05	-3.04e-05	-2.34e-05
	(5.64e-05)	(8.18e-06)	(7.99e-06)	(8.30e-06)	(4.46e-04)	(5.47e-05)	(5.63e-05)	(5.81e-05)
Spot Price	0.009***	7.90e-04***	8.28e-04***	8.47e-04***	0.016***	3.32e-04	3.22e-04	3.03e-04
	(7.60e-04)	(1.90e-04)	(2.06e-04)	(2.13e-04)	(0.001)	(2.07e-04)	(2.14e-04)	(2.20e-04)
Carbon Allowances	0.296***	-0.003	-0.006**	-0.006*	0.336***	-0.002*	-0.003**	-0.003**
	(0.027)	(0.003)	(0.003)	(0.003)	(0.027)	(0.001)	(0.001)	(0.001)
Gas	0.228***	-0.051***	-0.063***	-0.068***	0.038	-0.015	-0.016	-0.018
	(0.042)	(0.014)	(0.016)	(0.017)	(0.039)	(0.011)	(0.012)	(0.012)
Oil	-0.133***	-0.016***	-0.017***	-0.020***	-0.254***	-0.025***	-0.025***	-0.025***
	(0.047)	(0.003)	(0.003)	(0.003)	(0.035)	(0.002)	(0.002)	(0.002)
Coal	-0.211***	-0.005	6.27e-04	0.005	0.146***	-0.009	-0.009	-0.007
	(0.041)	(0.007)	(0.007)	(0.008)	(0.051)	(0.006)	(0.007)	(0.006)
Load	-7.20e-05	-1.27e-06	-1.00e-06	-9.44e-07	7.09e-06	-1.21e-07	-1.44e-07	-1.76e-07
	(4.66e-05)	(1.09e-06)	(1.04e-06)	(1.04e-06)	(5.64e-05)	(4.56e-07)	(4.46e-07)	(4.48e-07)
1st lag RP		0.980***	0.656***	0.628***		0.995***	0.898***	0.884***
		(0.004)	(0.011)	(0.011)		(0.001)	(0.017)	(0.019)
2nd lag RP			0.326***	0.221***			0.096***	-0.041***
			(0.009)	(0.017)			(0.017)	(0.010)
3rd lag RP				0.134***				0.152***
				(0.013)				(0.018)
Observations	23,865	23,643	23,416	23,195	23,864	23,640	23,411	23,188
R^2	0.188	0.978	0.980	0.980	0.104	0.988	0.987	0.987
Number of contractID	49	49	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***,** and *. Variance covariance estimator (VCE) robust regression estimates on risk premium with the open interest variable over peak and base contracts with differing lagged periods.

Table 24: VCE(robust) regression estimator with standard deviation

VARIABLES	**Peak**	**Peak 1L**	**Peak 2L**	**Peak 3L**	**Base**	**Base 1L**	**Base 2L**	**Base 3L**
Constant	0.278	-0.025*	-0.030**	-0.032**	-0.707	-0.012	-0.012	-0.012
	(0.459)	(0.015)	(0.015)	(0.016)	(0.553)	(0.009)	(0.010)	(0.010)
Standard Deviation	-0.097***	-8.87e-04	-1.18e-04	6.78e-04	-0.046***	-8.05e-04***	-6.26e-04**	-5.95e-05
	(0.029)	(0.001)	(9.84e-04)	(0.001)	(0.017)	(2.93e-04)	(3.06e-04)	(4.00e-04)
Skewness	-0.039***	-6.01e-04**	-9.44e-05	-4.05e-05	0.009**	3.06e-04*	4.02e-04**	3.26e-04
	(0.005)	(3.02e-04)	(3.24e-04)	(3.08e-04	(0.004)	(1.61e-04)	(1.96e-04)	(2.17e-04)
Variance	3.05e-04***	-3.76e-05***	-3.82e-05***	-4.01e-05***	0.001**	-5.52e-05	-4.84e-05	-4.26e-05
	(8.25e-05)	(8.85e-06)	(8.63e-06)	(8.99e-06)	(5.60e-04)	(5.76e-05)	(5.91e-05)	(6.05e-05)
Spot Price	0.010***	8.69e-04***	9.10e-04***	9.31e-04***	0.018***	4.12e-04*	4.04e-04*	3.84e-04
	(8.60e-04)	(1.86e-04)	(2.02e-04)	(2.08e-04)	(0.001)	(2.20e-04)	(2.27e-04)	(2.34e-04)
Carbon Allowances	0.182***	-0.008***	-0.010***	-0.009***	0.231***	-0.003**	-0.003**	-0.002*
	(0.040)	(0.003)	(0.003)	(0.003)	(0.020)	(0.001)	(0.001)	(0.001)
Gas	0.197***	-0.056***	-0.069***	-0.074***	0.077*	-0.019*	-0.018*	-0.022*
	(0.042)	(0.014)	(0.016)	(0.017)	(0.040)	(0.011)	(0.012)	(0.012)
Oil	-0.002	-0.011***	-0.013***	-0.016***	-0.148***	-0.023***	-0.023***	-0.023***
	(0.041)	(0.003)	(0.003)	(0.003)	(0.049)	(0.002)	(0.002)	(0.002)
Coal	-0.120***	-0.006	-4.67e-04	0.003	0.178***	-0.009	-0.009	-0.008
	(0.040)	(0.008)	(0.008)	(0.008)	(0.049)	(0.006)	(0.006)	(0.007)
Load	-7.39e-05	-1.50e-06	-1.23e-06	-1.16e-06	7.69e-06	-1.41e-07	-1.61e-07	-1.85e-07
	(4.69e-05)	(1.25e-06)	(1.20e-06)	(1.19e-06)	(5.54e-05)	(4.94e-07)	(4.85e-07)	(4.78e-07)
1st lag RP		0.979***	0.658***	0.629***		0.995***	0.904***	0.890***
		(0.004)	(0.012)	(0.012)		(0.001)	(0.018)	(0.021)
2nd lag RP			0.324***	0.217***			0.090***	-0.052***
			(0.009)	(0.017)			(0.018)	(0.010)
3rd lag RP				0.136***				0.157***
				(0.013)				(0.019)
Observations	22,706	22,472	22,245	22,027	22,706	22,470	22,241	22,022
R^2	0.208	0.977	0.979	0.979	0.129	0.986	0.986	0.987
Number of contractID	49	49	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***,** and *. Variance covariance estimator (VCE) robust regression estimates on risk premium with the standard deviation variable over peak and base contracts with differing lagged periods.

Table 25: Extended model on relationship between liquidity measurements and the risk premium using panel corrected standard errors (PCSE) method

VARIABLES		**Peak**			**Base**	
Constant	-0.047***	-0.022***	-0.025***	-0.013*	-0.012***	-0.012***
	(0.013)	(0.004)	(0.005)	(0.007)	(0.002)	(0.004)
Illiquidity	-3.807***			-3.777***		
	(0.350)			(0.199)		
Open Interest		-7.49e-06***			7.36e-07*	
		(1.52e-06)			(4.03e-07)	
Standard Deviation			-8.87e-04			-8.05e-04
			(1.00e-03)			(8.13e-04)
Skewness	-0.002*	-0.001***	-6.01e-04	-5.88e-04	3.45e-04	3.06e-04
	(0.001)	(3.84e-04)	(3.95e-04)	(6.90e-04)	(2.64e-04)	(3.39e-04)
Variance	8.90e-06	-2.92e-05***	-3.76e-05***	-1.43e-04***	-3.82e-05**	-5.52e-05**
	(1.70e-05)	(5.87e-06)	(6.12e-06)	(5.00e-05)	(1.89e-05)	(2.42e-05)
Spot Price	9.40e-04***	7.90e-04***	8.69e-04***	4.09e-04***	3.32e-04***	4.12e-04***
	(8.30e-05)	(3.13e-05)	(3.44e-05)	(7.63e-05)	(3.21e-05)	(4.48e-05)
Carbon Allowances	0.018	-0.003	-0.008*	-0.010	-0.002	-0.003
	(0.013)	(0.004)	(0.004)	(0.007)	(0.002)	(0.003)
Gas	-0.095***	-0.051***	-0.056***	-0.046***	-0.015***	-0.019***
	(0.022)	(0.006)	(0.006)	(0.011)	(0.004)	(0.005)
Oil	-0.011	-0.016***	-0.011**	0.006	-0.024***	-0.023***
	(0.016)	(0.004)	(0.005)	(0.009)	(0.003)	(0.004)
Coal	0.072***	-0.005	-0.006	-0.002	-0.009*	-0.009
	(0.026)	(0.008)	(0.008)	(0.014)	(0.005)	(0.006)
Load	-2.43e-07	-1.27e-06***	-1.50e-06***	-8.68e-08	-1.21e-07	-1.41e-07
	(1.31e-06)	(4.51e-07)	(4.65e-07)	(6.66e-07)	(2.40e-07)	(3.47e-07)
1st lag RP	0.971***	0.980***	0.979***	0.991***	0.995***	0.995***
	(0.005)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Observations	1,954	23,643	22,472	3,707	23,640	22,470
R^2	0.972	0.978	0.977	0.988	0.987	0.986
Number of contractID	49	49	49	49	49	49

Significance at the 1%, 5% and 10% level marked with respectively ***, ** and *. Panel corrected standard errors (PCSE) regression estimates on risk premium with the first lagged dependent variable included. Distinction between peak and base contracts and three different measurements for liquidity in the market: (Il)liquidity, open interest and standard deviation.

Table 26: PCSE regression estimator with (Il)liquidity

VARIABLES	Peak	Peak 1L	Peak 2L	Peak 3L	Base	Base 1L	Base 2L	Base 3L
Constant	-0.971***	-0.041***	-0.047***	-0.039***	-1.479***	-0.013*	-0.009	-0.007
	(0.063)	(0.013)	(0.013)	(0.012)	(0.055)	(0.007)	(0.007)	(0.007)
Illiquidity	-4.621**	-3.807***	-3.788***	-3.707***	-7.378***	-3.777***	-3.877***	-3.807***
	(1.811)	(0.350)	(0.350)	(0.333)	(1.573)	(0.199)	(0.200)	(0.200)
Skewness	-0.055***	-0.002*	-0.002	-0.002	0.044***	-5.88e-04	-1.07e-04	-7.73e-05
	(0.007)	(0.001)	(0.001)	(0.001)	(0.006)	(6.90e-04)	(6.93e-04)	(6.95e-04)
Variance	5.96e-04***	8.90e-06	5.09e-06	-1.48e-05	-0.002***	-1.43e-04***	-1.55e-04***	-1.64e-04***
	(1.04e-04)	(1.70e-05)	(1.72e-05)	(1.71e-05)	(3.69e-04)	(5.00e-05)	(5.00e-05)	(5.00e-05)
Spot Price	0.005***	9.40e-04***	9.47e-04***	9.83e-04***	0.000***	4.09e-04***	4.19e-04***	4.13e-04***
	(4.00e-04)	(8.30e-05)	(8.24e-05)	(7.89e-05)	(5.64e-04)	(7.63e-05)	(7.63e-05)	(7.68e-05)
Carbon Allowances	-0.564***	0.018	0.009	0.018	-0.790***	-0.010	-0.007	-0.007
	(0.068)	(0.013)	(0.013)	(0.013)	(0.058)	(0.007)	(0.007)	(0.007)
Gas	0.0604	-0.095***	-0.093***	-0.120***	-0.423***	-0.046***	-0.053***	-0.058***
	(0.115)	(0.022)	(0.022)	(0.022)	(0.095)	(0.011)	(0.011)	(0.011)
Oil	-0.744***	-0.011	-0.019	0.004	-1.035***	0.006	0.008	0.011
	(0.096)	(0.016)	(0.017)	(0.016)	(0.084)	(0.009)	(0.009)	(0.009)
Coal	0.263**	0.072***	0.077***	0.070***	1.132***	-0.002	-0.002	-0.002
	(0.129)	(0.026)	(0.026)	(0.025)	(0.107)	(0.014)	(0.014)	(0.014)
Load	5.86e-05***	-2.43e-07	-1.95e-07	-1.03e-06	1.13e-04***	-8.68e-08	-3.88e-07	-5.70e-07
	(6.25e-06)	(1.31e-06)	(1.30e-06)	(1.22e-06)	(5.29e-06)	(6.66e-07)	(6.67e-07)	(6.67e-07)
1st lag RP		0.971***	0.731***	0.623***		0.991***	0.853***	0.837***
		(0.005)	(0.030)	(0.030)		(0.002)	(0.024)	(0.024)
2nd lag RP			0.244***	-0.019			0.139***	0.038
			(0.030)	(0.035)			(0.024)	(0.032)
3rd lag RP				0.380***				0.119***
				(0.029)				(0.025)
Observations	1,978	1,954	1,914	1,893	3,752	3,707	3,657	3,605
R^2	0.269	0.972	0.973	0.977	0.277	0.988	0.988	0.989
Number of contractID	49	49	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***,** and *. Panel corrected standard errors (PCSE) regression estimates on risk premium with the (Il)liquidity variable over peak and base contracts with differing lagged periods.

Table 27: PCSE regression estimator with open interest

VARIABLES	**Peak**	**Peak 1L**	**Peak 2L**	**Peak 3L**	**Base**	**Base 1L**	**Base 2L**	**Base 3L**
Constant	0.211***	-0.022***	-0.026***	-0.027***	-0.676***	-0.012***	-0.012***	-0.011***
	(0.024)	(0.004)	(0.004)	(0.004)	(0.029)	(0.002)	(0.002)	(0.004)
Open Interest	-7.85e-05***	-7.49e-06***	-8.62e-06***	-8.89e-06***	1.94e-05***	7.36e-07*	8.11e-07*	1.16e-06**
	(8.70e-06)	(1.52e-06)	(1.48e-06)	(1.48e-06)	(4.10e-06)	(4.03e-07)	(4.30e-07)	(5.57e-07)
Skewness	-0.087***	-0.001***	-5.84e-04	-5.51e-04	-0.024***	3.45e-04	4.26e-04	3.04
	(0.002)	(3.84e-04)	(3.71e-04)	(3.72e-04)	(0.003)	(2.64e-04)	(2.71e-04)	(3.36)
Variance	-6.17e-04***	-2.92e-05***	-2.83e-05***	-2.92e-05***	5.27e-04**	-3.82e-05**	-3.04e-05	-2.34e-05
	(3.10e-05)	(5.87e-06)	(5.67e-06)	(5.69e-06)	(2.10e-04)	(1.89e-05)	(1.93e-05)	(2.39e-05)
Spot Price	0.009***	7.90e-04***	8.28e-04***	8.46e-04***	0.015***	3.32e-04***	3.22e-04***	3.03e-04***
	(1.61e-04)	(3.13e-05)	(3.02e-05)	(3.01e-05)	(3.11e-04)	(3.21e-05)	(3.35e-05)	(4.08e-05)
Carbon Allowances	0.076***	-0.003	-0.006*	-0.006*	0.140***	-0.002	-0.003	-0.003
	(0.020)	(0.004)	(0.003)	(0.003)	(0.023)	(0.002)	(0.002)	(0.003)
Gas	0.145***	-0.051***	-0.063***	-0.068***	-0.042	-0.015***	-0.016***	-0.018***
	(0.033)	(0.006)	(0.006)	(0.006)	(0.038)	(0.004)	(0.004)	(0.005)
Oil	-0.388***	-0.016***	-0.017***	-0.020***	-0.700***	-0.025***	-0.025***	-0.025***
	(0.025)	(0.004)	(0.004)	(0.004)	(0.027)	(0.003)	(0.003)	(0.004)
Coal	-0.723***	-0.005	6.27e-04	0.005	-0.153***	-0.009*	-0.009*	-0.007
	(0.044)	(0.008)	(0.008)	(0.008)	(0.050)	(0.005)	(0.005)	(0.006)
Load	-6.33e-05***	-1.27e-06***	-1.00e-06**	-9.44e-07**	9.10e-06***	-1.21e-07	-1.44e-07	-1.76e-07
	(2.39e-06)	(4.51e-07)	(4.34e-07)	(4.33e-07)	(2.68e-06)	(2.40e-07)	(2.44e-07)	(3.40e-07)
1st lag RP		0.980***	0.656***	0.628***		0.995***	0.898***	0.884***
		(0.001)	(0.010)	(0.010)		(0.001)	(0.009)	(0.011)
2nd lag RP			0.326***	0.221***			0.096***	-0.041***
			(0.010)	(0.014)			(0.009)	(0.015)
3rd lag RP				0.134***				0.152***
				(0.012)				(0.012)
Observations	23,865	23,643	23,416	23,195	23,864	23,640	23,411	23,188
R^2	0.299	0.978	0.980	0.980	0.144	0.987	0.987	0.987
Number of contractID	49	49	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***,** and *. Panel corrected standard errors (PCSE) regression estimates on risk premium with the open interest variable over peak and base contracts with differing lagged periods.

Table 28: PCSE regression estimator with standard deviation

VARIABLES	**Peak**	**Peak 1L**	**Peak 2L**	**Peak 3L**	**Base**	**Base 1L**	**Base 2L**	**Base 3L**
Constant	0.246***	-0.025***	-0.030***	-0.032***	-0.444***	-0.012***	-0.012***	-0.012***
	(0.025)	(0.005)	(0.005)	(0.005)	(0.029)	(0.004)	(0.004)	(0.004)
Standard Deviation	-0.070***	-8.87e-04	-1.18e-04	6.78e-04	-0.226***	-8.05e-04	-6.26e-04	-5.95e-05
	(0.005)	(0.001)	(9.71e-04)	(9.75e-04)	(0.006)	(8.13e-04)	(8.19)	(8.21e-04)
Skewness	-0.079***	-6.01e-04	-9.44e-05	-4.05e-05	-0.040***	3.06e-04	4.02e-04	3.26e-04
	(0.002)	(3.95e-04)	(3.83e-04)	(3.84e-04)	(0.002)	(3.39e-04)	(3.41e-04)	(3.41e-04)
Variance	-5.61e-04***	-3.76e-05***	-3.82e-05***	-4.01e-05***	6.04e-04***	-5.52e-05**	-4.84e-05**	-4.26e-05*
	(3.17e-05)	(6.12e-06)	(5.91e-06)	(5.94e-06)	(2.02e-04)	(2.42e-05)	(2.42e-05)	(2.40e-05)
Spot Price	0.009***	8.69e-04***	9.10e-04***	9.31e-04***	0.015***	4,12e-04***	4.04e-04***	3.84e-04***
	(1.73e-04)	(3.44e-05)	(3.31e-05)	(3.30e-05)	(3.34e-04)	(4.48e-05)	(4.51e-05)	(4.51e-05)
Carbon Allowances	-0.079***	-0.008*	-0.010***	-0.009**	-0.272***	-0.003	-0.003	-0.002
	(0.021)	(0.004)	(0.004)	(0.004)	(0.024)	(0.003)	(0.003)	(0.003)
Gas	0.133***	-0.056***	-0.069***	-0.074***	0.039	-0.019***	-0.019***	-0.022***
	(0.033)	(0.006)	(0.006)	(0.006)	(0.037)	(0.005)	(0.005)	(0.005)
Oil	-0.279***	-0.011**	-0.013***	-0.016***	-0.334***	-0.023***	-0.023***	-0.023***
	(0.026)	(0.005)	(0.004)	(0.005)	(0.028)	(0.004)	(0.004)	(0.004)
Coal	-0.678***	-0.006	-4.67e-04	0.003	0.001	-0.009	-0.009	-0.008
	(0.044)	(0.008)	(0.008)	(0.008)	(0.05)	(0.006)	(0.007)	(0.006)
Load	-6.44e-05***	-1.50e-06***	-1.23e-06***	-1.16e-06***	1.13e-05***	-1.41e-07	-1.61e-07	-1.85e-07
	(2.40e-06)	(4.65e-07)	(4.48e-07)	(4.47e-07)	(2.64e-06)	(3.47e-07)	(3.48e-07)	(3.48e-07)
1st lag RP		0.979***	0.658***	0.629***		0.995***	0.904***	0.890***
		(0.002)	(0.010)	(0.011)		(0.001)	(0.011)	(0.011)
2nd lag RP			0.324***	0.217***			0.090***	-0.052***
			(0.010)	(0.014)			(0.011)	(0.015)
3rd lag RP				0.136***				0.157***
				(0.012)				(0.012)
Observations	22,706	22,472	22,245	22,027	22,706	22,470	22,241	22,022
R^2	0.303	0.977	0.979	0.979	0.201	0.986	0.986	0.987
Number of contractID	49	49	49	49	49	49	49	49

Robust standard errors in paranthesses, significance at the 1%, 5% and 10% level marked with respectively ***,** and *. Panel corrected standard errors (PCSE) regression estimates on risk premium with the standard deviation variable over peak and base contracts with differing lagged periods.

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