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An Empirical Analysis of Futures Pricing in the Nordic Electricity Market

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"[Master thesis, MSc, Finance]"

NORWEGIAN SCHOOL OF ECONOMICS

Abstract

The aim of this paper is to study the pricing of futures contracts relative to expected future spot prices in the Nordic electricity market. Data set of 1–6 weeks ahead weekly and 1–6 months ahead monthly futures is used to identify whether futures premium is present in the Nordic market. The findings reveal that short term futures contracts are unbiased predictors of the future spot prices. However, at longer maturities (5–6 weeks for weekly contracts and 2–6 months for monthly ones) significant time-varying futures premium exists. This premium is positive on average and doesn’t vary significantly by seasons. Furthermore, the magnitude of the premium is found to be substantially higher than in other commodity markets. Finally, a link between the futures premium and measures of risk (reservoir level, variance and skewness of the spot prices) is tested to find out whether the premium exists as a compensation for risk or mispricing in the market. The futures premium is found to be positively related to the reservoir level, while relationship with variance and skewness of the spot prices is mostly insignificant. As the magnitude of the premium is too high to be explained by this sole risk factor, it is concluded that mispricing exists in futures contracts with maturities longer than 4 weeks in the Nordic electricity market.

Keywords: Futures, Nordic electricity market, futures premium, reservoir level, skewness, variance.

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1. Introduction

During the 1990s many power markets around the world were transformed from being government-controlled to deregulated local markets, where consumers are allowed to choose their electricity suppliers (Bierbrauer et al., 2007). Norway was one of the first countries to liberalize its electricity sector. New Energy Act was passed in 1990, which laid the legal foundation for the reform, and the Norwegian electricity market became deregulated in 1991 (Bye & Hope, 2005). Supply and generation was separated from transmission and distribution in order to create competition and improve previously inefficiently operated system. It was followed by establishment of the Norwegian power exchange in 1993. Such system ensures publicly available information for market participants that could be used to bid on the quantity and price of the electricity they desire to trade.

Uncertainty about volume and price of the electricity after the deregulation has created a complex market characterized by high volatility and occasional spikes (Redl et al., 2009). This condition motivates the suppliers and retailers to be more flexible with their strategies and develop innovative features in their products, that could not exist in an otherwise regulated market. An example of such products is financial derivatives designed for hedging and speculation purposes. This paper focuses on futures contracts and their pricing mechanism. Using these contracts market participants can effectively lock up their desired price for buying and selling electricity.

What makes the Nordic electricity futures contracts interesting to study is their relatively large futures premium that averages 7–9% on a monthly basis (Gjølberg & Brattested, 2011). Theoretically the futures premium should be a price of risk that the hedger is willing to pay to eliminate it. The magnitude of the premium in the Nordic futures market indicates an unreasonably high price for risk compared to other commodity markets. As a result, the research question is formulated:

Can the existing futures premium be explained as a compensation for risk?

To answer the research question, the study is performed in three stages. First, we identify futures contracts with significant futures premium. Then these particular contracts are used to analyze the properties of the premium. Lastly, we test sensitivity of the futures premium to measures of economic risk that are likely to have effect on its magnitude.

Our study contributes to the existing literature by studying both monthly and weekly futures contracts with various times to maturity. This allows investigating how time to maturity affects the predictive power of the futures contracts and their sensitivity to measures of economic risk. The latest data until January 2016 is used to achieve the most relevant results.

The study is practically relevant from various aspects. Firstly, forecasting power of the Nordic futures market is tested. The tests would show whether futures prices reliably forecast future spot prices, which can help market participants hedging their risks more effectively. Secondly, in case of the futures prices being biased, the study would benefit traders who could create profitable trading strategies based on the findings. Finally, factors influencing magnitude of the futures premium are found, which adds to the ability of market participants to manage their risk. They can optimize quantities bought or sold in advance based on changes in the futures premium and exposure to certain factors.

This paper is structured as follows. Section 2 is an introduction to the Nordic electricity market, its structure and main sources of production. This sheds light on some of the properties of the market that can potentially play a role in variation of the futures premium. On the third section, we review theoretical background and available literature in pricing of futures contracts and premiums. Section 4 presents the data description. It is followed by the methodology in section 5. Section 6 presents the results and discussion. Lastly, conclusion is laid out in Section 7.

2. Nordic electricity market

In 1996 a common market was created between Norway and Sweden – Nord Pool ASA, the world's first international power exchange. The market was later joined by other countries such as Finland in 1998 and Denmark in 2002. In the same year Nord Pool Spot AS became a separate company to organize Nord Pool's spot activities in the form of a physical market place. After 2010, Estonia, Lithuania and Latvia became a part of the Nordic electricity network (Nord Pool, 2016e). As Europe's leading power market, Nord Pool Spot provides day-ahead (Elspot) and intraday (Elbas) electricity market to the customers, guaranteeing settlement and delivery over 380 companies and 20 countries that trade on this market (Nord Pool, 2016a).

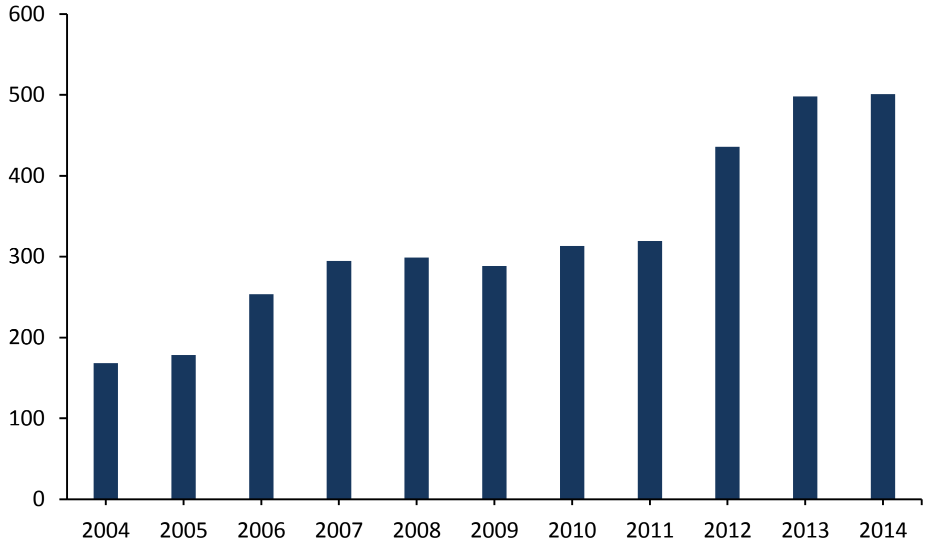

Figure 1. Traded volume in the Nordic day-ahead electricity market (in TWh). Adapted from Nord Pool Spot, 2015.

Historically the price of electricity in the Nordic region was low due to the large share of cost effective hydro and nuclear power. Hence, the electricity consumption is relatively higher than in other European countries. Average temperature plays an important role in the Nordic energy consumption pattern. Since electricity in the Nordic countries is extensively used for heating purposes, the demand for electricity increases in colder periods (Nordic Energy Regulators, 2014). As shown in Figure 2, the consumption is lowest in summer and highest in winter. In order, highest generation and consumption in Nordic electricity market belongs to Sweden, Norway, Finland and Denmark. Norway is the only country with positive net export of power, while consumption in all other mentioned countries exceeds production (Nordic Energy Regulators, 2014).

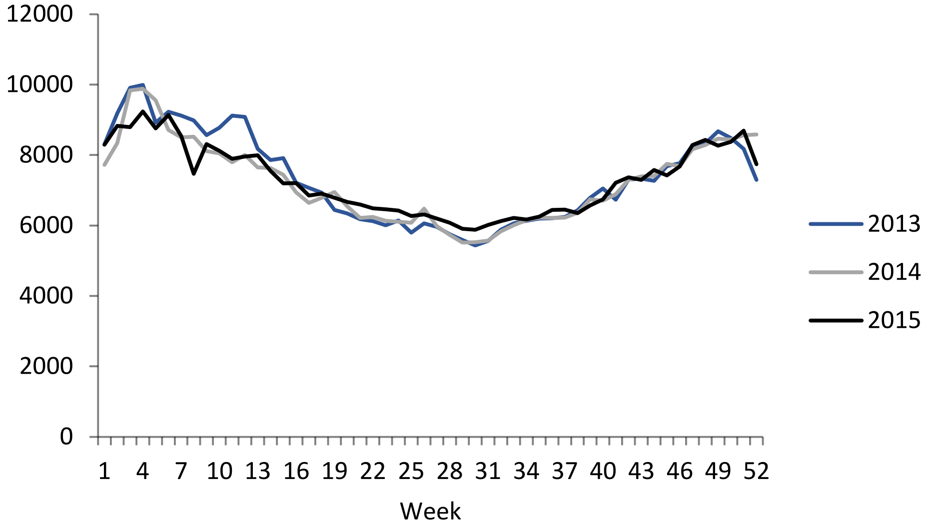

Figure 2. Electricity consumption in the Nordic region (GWh per week), 2013-2015. Adapted from Nord Pool Spot, 2016.

Electricity is a secondary source of energy because it is generated from conversion of primary sources of energy such as coal, nuclear, solar or wind. In Nordic Market main sources of energy to generate electricity are hydro, nuclear, fossil, wind and biomass. As shown in Figure 3, electricity generation in Nordic Market is dominated by the hydropower. Half of the generation in Sweden and virtually the entire generation in Norway is coming from this particular source of energy (Rubino, et al., 2016). Nuclear power, which is the second largest source of power generation in Sweden, delivers almost a quarter of total electricity output in the Nordic region. All the renewable sources such as wind and biomass alongside fossil fuels only make up to a quarter of power generation in Nordic electricity market. Fossil fuels could be further separated into smaller components, out of which coal has the largest share of power generation, followed by natural gas, peat and lastly oil with the lowest share (Nordic Energy Regulators, 2014).

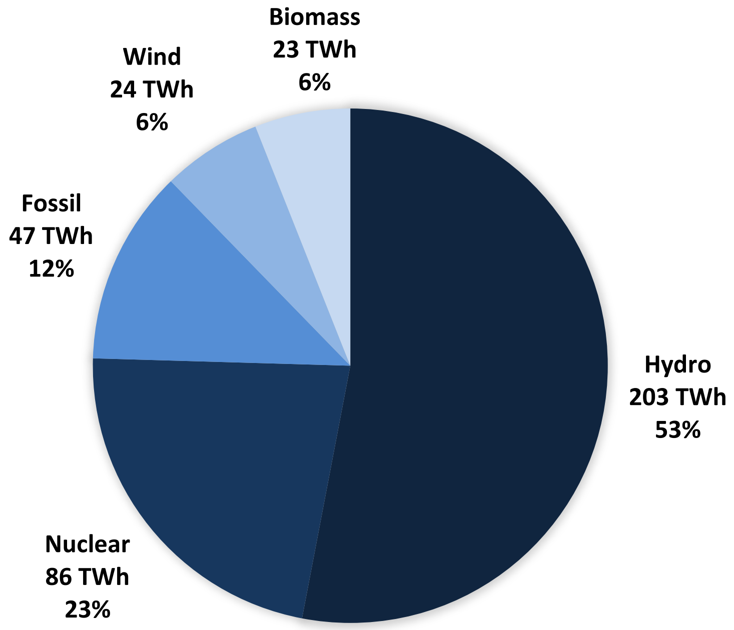

Figure 3. Electricity generation by power source in the Nordic region, 2013. Adapted from Nordic Energy Regulators, 2014.

Hydropower generation depends on the water reservoir level, which is highest in fall and lowest in spring, as illustrated in Figure 4. Seasonal changes in reservoir level are explained by consumption and inflow levels. Consumption declines in warmer seasons because less energy is used for heating purposes. At the same time, higher temperature results in snow melting process, which has a major contribution in inflows to the water reservoirs. As a result of these two factors, the reservoir level gradually rises during warmer seasons. The process continues until fall, when the reservoirs reach their maximum level. This stored energy is then used to satisfy the increased demand in colder periods. High demand and lower inflow in winter reduce the levels of water reservoirs to their minimum at the beginning of spring (Nordic Energy Regulators, 2014).

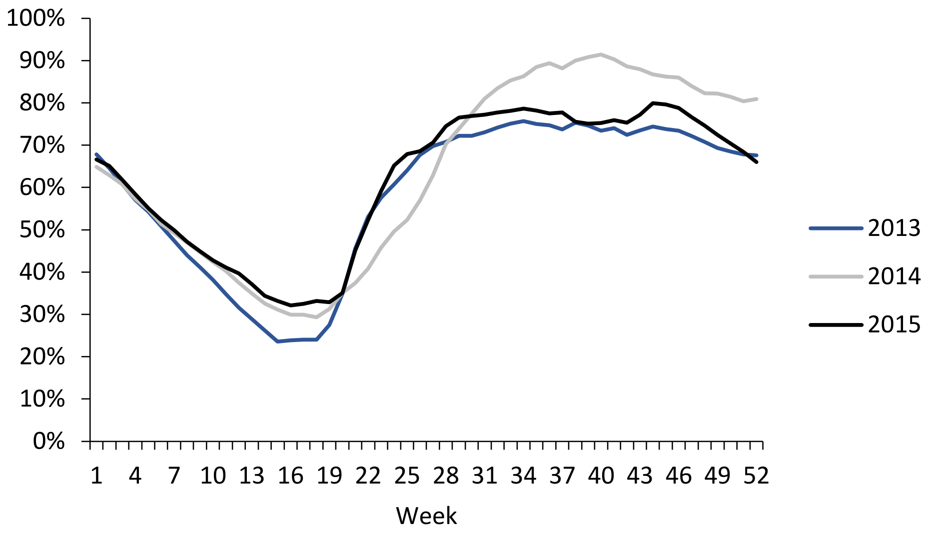

Figure 4. Reservoir level in the Nordic region as a percentage of total capacity. Adapted from Nord Pool Spot, 2016.

The Nordic electricity market is divided into several biding areas. Transmission capacity varies among these areas, which results in price differences. Transmission system operators in each country decide the number of the bidding areas for that country. Today Sweden is divided into four different areas, Norway into five, Denmark into two, while Finland, Lithuania, Latvia and Estonia each have one bidding area. Power always goes from the low price areas to the high price areas to ease the price differences among them (Nord Pool, 2016b). The entire electricity trading for all the areas is organized through Elspot (day-ahead) and Elbas (intraday) markets.

2.1 Elspot market

On Elspot day-ahead market, hourly contracts are traded corresponding to the next day's 24 hours period. After market participants make their offers for all the areas at 12:00 CET, an algorithm is applied to calculate the hourly prices by obtaining the equilibrium between the aggregate supply and demand curves assuming no restrictions on the transmission capacity. The average of the calculated spot prices throughout the day is called the system price (Nord Pool, 2016c). Weekly system prices for the years 2009–2016 are presented in figure 5, and figure 6 shows monthly prices during October 2003–January 2016. In the physical market, a set of different hourly prices is assigned for each area after accounting for constraints and costs of the power grid (Nord Pool, 2016b).

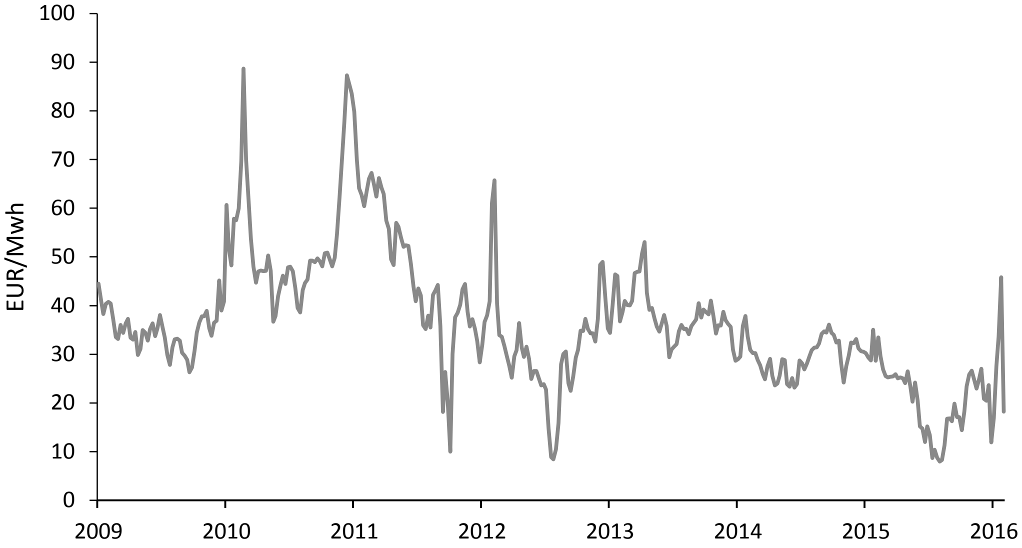

Figure 5. Average weekly spot prices in the Nordic region during January 2009–January 2016 (measured in EUR/MWh). Adapted from Nord Pool Spot, 2016.

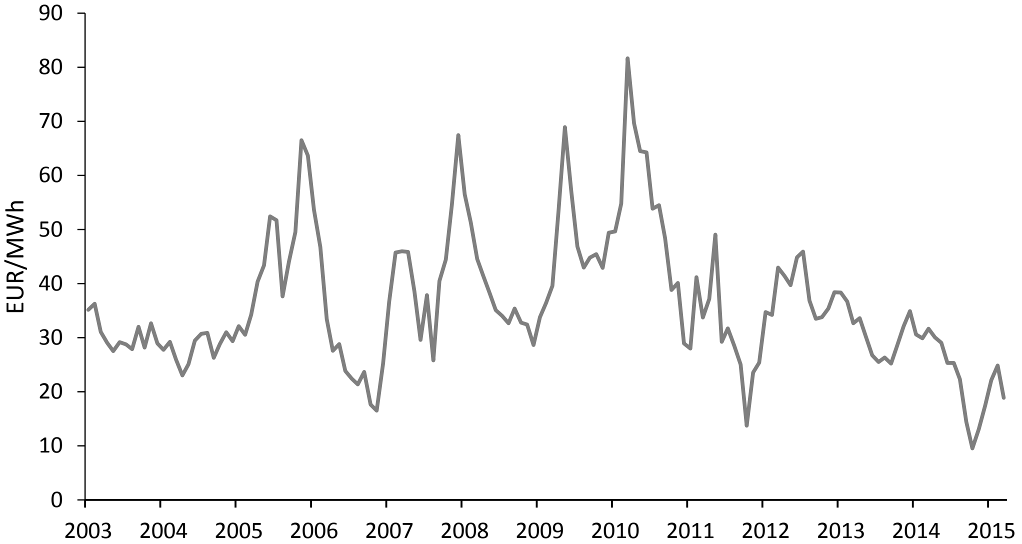

Figure 6. Average monthly spot prices in the Nordic region during October 2003–December 2015 (measured in EUR/MWh). Adapted from Nord Pool Spot, 2016.

2.2 Elbas market

The Elbas intraday market is used to trade electricity up to one hour before delivery. Everyday members within or across the border offer the amount of electricity they want to buy or sell at a particular price. The trading mechanism is based on a first come first served basis between buyers and sellers. The Elbas market allows market participants adjusting their power production and consumption plans very close to the delivery time. Thus, the role of the intraday market is to smooth the electricity supply and demand which otherwise could lead to day-ahead market imbalances and price fluctuations (Lucia & Schwartz, 2002).

2.3 NASDAQ OMX – financial market

Financial market, as a clearing house, guarantees trading and settlements as well as ensures equal access to information for all market participants (Rademaekers et al., 2008). The major function of the financial market is to provide financial securities for risk management purposes. In 2008 NASDAQ OMX became the financial market for Nord Pool by acquiring the Nord Pool clearing market and establishing NASDAQ OMX commodities (NASDAQ, 2010). In addition, NASDAQ OMX operates as the financial market throughout Europe for other electricity markets besides Nord Pool Spot such as EEX in Germany and EPEX Spot in France, Austria, Germany, Switzerland and Luxembourg. Futures, DS futures (deferred settlement), EPADs (Electricity price area differentials) and Options are among the many financial products that are traded in the Nordic market with a minimum contract size of 1MW. To promote liquidity, the financial products offered in the market are based on the system price. This price doesn’t account for the technical issues related to the transmission costs and capacities in different bidding areas (Nord Pool, 2016d).

3. Theory and previous empirical findings

This section provides the necessary theoretical background and relevant findings from existing literature. First, we define key concepts. Then we explain two main theories used in pricing commodities. Lastly, an overview of previous empirical findings is provided.

3.1 Important definitions

3.1.1 Futures contracts

Futures contracts provide an obligation to buy or sell an underlying asset at some specific future date at a predetermined price (McDonald, 2012). These contracts are standardized and traded in an exchange. There is no physical delivery in the Nordic electricity futures market and daily cash settlements are used instead to compensate for movements in the spot price. These cash settlements are made based on the Nordic system prices during the delivery period (Nord Pool, 2016d). The terms of futures contracts allow buyers and sellers to hedge their exposure to possible price fluctuation in the future. Futures contracts on electricity are in the form of weekly, monthly, quarterly and yearly contracts.

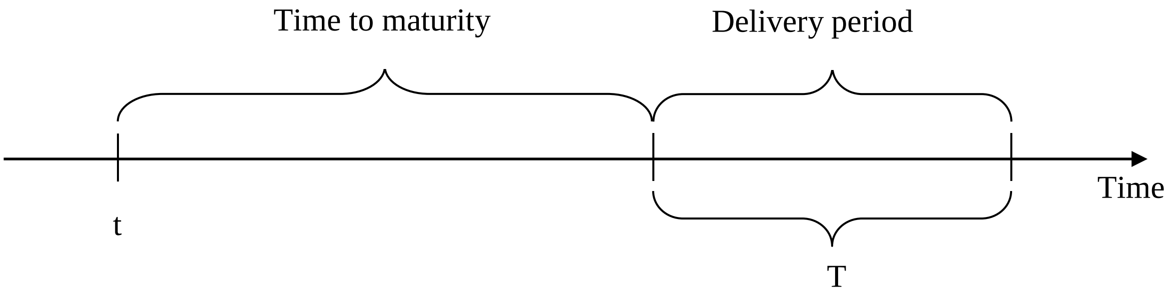

Figure 7. Explanation of the terms related to futures contracts.

To avoid confusion, figure 7 is created to illustrate features of futures contracts that will be used later throughout the paper. Futures contracts are purchased or sold during the trading period (time t), while the delivery period takes place in time T. We are analyzing weekly and monthly contracts in the Nord Pool market that have different length of delivery periods. As their name indicates, weekly contracts are agreements for a delivery period of 1 week, while monthly contracts have a delivery period of 1 month. Time period from the moment the contract is traded (at time t) to the start of the delivery period (at time T) is called time to maturity. It is measured in weeks for weekly futures and in months for monthly contracts.

3.1.2 Basis

Another important concept in commodity market is basis, which is defined as the difference between futures price and spot price at any given time.

$$\boldsymbol{Basis_{t,T} = F_{t,T} - S_t} \tag{1}$$

where t is the time when the futures contract is purchased and T is the time when it matures; $\boldsymbol{F_{t,T}}$ is the price of the futures contract at time t that matures at T and $\boldsymbol{S_t}$ is the price of the underlying at time t.

One of the main sources of volatility in basis is seasonal changes in supply and demand. Inventories however can smooth these variations in basis by responding to expected spot price changes. A high basis generally indicates a high cost of storage in the market. Therefore, in markets with high storage cost and seasonal supply and demand, we observe higher standard deviation in basis (Fama & French, 1987).

3.1.3 Futures premium

Futures premium, defined as the bias of the futures prices in forecasting the future spot prices, shows the difference between futures price during trading period (t) and expected future spot price during delivery period (T),

$$\boldsymbol{FP_{t,T} = F_{t,T} - E_t[S_T]} \tag{2}$$

where $\boldsymbol{FP_{t,T}}$ represents futures premium for contracts traded in time t with delivery period at time T; $\boldsymbol{F_{t,T}}$ is the price of such futures contract; and $\boldsymbol{E_t[S_T]}$ is an expectation at time t for the spot price at time T.

In some cases in the literature, the term risk premium is used to study the futures contracts. Some authors use the term as an equivalent to futures premium – see Gjølberg and Brattested (2011), Bessembinder and Lemmon (2002). While other authors define it differently from the futures premium and focus their study on the presence of risk premium in futures market – see Botterud et al. (2010), Weron and Zator (2014). To prevent any further confusion, we explain the difference. Risk premium for futures contracts in finance literature is defined as the difference between the expected spot price for the delivery period and the futures price (Weron & Zator, 2014),

$$\boldsymbol{RP_{t,T} = E_t[S_T] - F_{t,T}} \quad \textbf{(3)}$$

Comparing model (2) with model (3) it is visible that futures premium is equal to the risk premium with the opposite sign. Using any of these concepts is a matter of preference in the methodology. However, the term risk premium implies that the premium is present as a compensation for risk, which is not necessarily the case in the Nordic electricity market. Consequently, we use the term futures premium in this paper. To avoid confusion with different definitions in the literature, the review of the existing findings is written in accordance with the definition of futures premium.

3.2 Pricing of commodity futures contracts

There are two main theories used in pricing commodity futures – theory of storage and expectation hypothesis. As the name implies, the former is used to price commodities that can be stored, while the latter could be used for any type of commodity. Usually, electricity is a non-storable commodity and therefore has to be priced by the expectation hypothesis. However, presence of water reservoirs creates a unique situation in the Nordic market, where electricity can be stored. In addition, only producers have this option while consumers have no such possibility. Therefore, in presence of water reservoirs, both pricing theories are relevant in pricing futures contracts of electricity, which can be considered a partly storable commodity.

3.2.1 Theory of storage

Theory of storage is a conventional approach toward pricing commodity futures that has roots in no-arbitrage argument. We consider a possible strategy for arbitrage, cash-and-carry (McDonald, 2012), to illustrate the pricing of a commodity futures contract and the related concepts for storable commodity markets such as storage cost and convenience yield.

In the case of cash-and-carry arbitrage, we assume that we own one unit of commodity. One option is to sell the commodity today (time t) and receive S_t. Another is to store the commodity, sell it at a future time T and receive S_T. The argument is that both options should provide the same pay-off in an efficient market without an arbitrage opportunity. By storing the commodity, we have to undertake the cost of storing. At the same time, there is an advantage in holding the commodity, because it could be put in use to meet an unexpected demand. This fact creates a non-monetary value called *Convenience Yield*. In case of continuously compounded interest rates, the no-arbitrage condition is formulated below,

$$\boldsymbol{F_{t,T} = S_t e^{(r+\lambda-c)(T-t)}} \qquad \textbf{(4)}$$

where **r** is the risk-free rate to compensate for the value of time, **λ** presents the cost of storage and **c** is the convenience yield. One rational indication from the parity above is that the magnitude of convenience yield has a negative relationship with expectation about availability of the commodity in the future. In another word, if market expects that the supply of commodity will be low in the future, holding it has higher value for the producer due to the higher probability of shortage incidents, while in the opposite case the convenience yield is lower (Hull, 2009).

3.2.2 Expectation hypothesis

Outside of the Nordic region, reliance on hydropower to generate electricity is limited. Absence of water reservoirs results in electricity being a non-storable commodity, making it impossible to apply no arbitrage argument. Expectation hypothesis is an approach that can be used to price non-storable commodities. According to this theory, the difference between the futures price and the current spot price is determined by combination of an expected change in the spot price and a futures premium (Fama & French, 1987). In other words, the futures price is equal to the expected spot price during the delivery period plus the futures premium component:

$$\boldsymbol{F_{t,T} = E_t[S_T] + FP_{t,T}} \qquad (5)$$

where t represents time when the contract is purchased and T is time when it matures; $\boldsymbol{F_{t,T}}$ is the price of the futures contract at date t with the delivery period at time T; $\boldsymbol{E_t[S_T]}$ is an expectation of the future spot price S_T at time t; and $\boldsymbol{FP_{t,T}}$ is the futures premium for a period from time t to time T. Fama and French (1987) defines this premium as a bias of the futures price in forecasting of the futures spot price. This bias can be both positive and negative. Gjølberg and Brattested (2011) explain this using an argument of time-varying hedging supply and demand. In a balanced market, where hedging supply and demand are matching, risk premium is zero. Therefore, the price of the futures contract should be a non-biased prediction of the future spot price. However, with an imbalance between hedging supply and demand, the price of the futures contract deviates from the expected future spot price.

It is important to mention that the expectation hypothesis and the theory of storage are alternatives but they are not contradicting each other. As Fama and French (1987) explained, variation in the futures premium (according to the expectation hypothesis) translates to variation in the interest rate, the storage cost, or convenience yield (according to the theory of storage). To illustrate this they used an example from agriculture, when basis for commodities is usually negative before a harvest with delivery period being after the harvest. Using the theory of storage, the negative basis is caused by low inventories that result in a larger convenience yield relative to interest and storage costs. Using the expectation hypothesis, the basis becomes negative as the futures prices are low because the spot prices are expected to fall after the harvest when inventories will substantially increase. In the case of trading futures contracts after the harvest with the delivery before the next one, the theory of storage implies a positive basis that could be explained by low convenience yield relative to storage and interest costs when inventories are high. Equivalently, the expectation hypothesis predicts a positive basis is explained by an expected rise in the spot prices in the future when supply is limited.

3.3 Previous empirical findings on futures premium

In this section we will overview previous empirical findings on the futures premium. There are two general areas of research related to the subject. First one is concerned with testing the presence of futures premium, while the other one aims to explain whether futures premium is a result of various risk factors in the market.

3.3.1 Empirical findings on presence of futures premium

Economic theory suggests that risk-averse producers of a commodity are willing to hedge their revenue by shorting futures contracts at a lower price than the expected spot. They essentially transfer their risk to speculators in the market by giving them a discount. Based on this notion, Keynes (as cited in Fama & French, 1987) predicts that the expected spot prices should be higher than the futures prices due to the hedging pressure from the producer. This condition is known in the literature as “normal-backwardation”.

Fama and French (1987) applied the expectation hypothesis as a new approach toward futures premium. As shown in formula (5), this approach splits the futures price into two components, one that forecasts the future spot price and the futures premium. Their aim was to find a relationship between the forecasting power and the presence of a time-varying futures premium in the market. By examining 21 commodity markets, they found strong evidence for normal-backwardation in those markets. However, they did not succeed to find strong evidence of the presence of the futures premium.

A study of the Nordic market by Gjølberg and Johnsen (2001) analyzes monthly futures prices since the beginning of the deregulated market in 1995 until January 2001. They show that the prices of futures tend to significantly over shoot the future spot prices, which implies the opposite of backwardation, a condition called “contango”. Gjølberg and Johnsen (2001) argue that in the Nordic market, where more than 90 percent of electricity production is coming from hydropower, producers have an advantage of effective storage of electricity unlike the buyer side. This asymmetric condition creates more hedging pressure from the buyer side and causes the futures prices to rise as the buyers are willing to pay more to hedge their risk. They also conclude that forecasting errors are so high that they can hardly be attributable to risk only and suggest that there is inefficiency present in the market.

Botterud et al. (2002) study the presence of futures[1] premium in the Nordic electricity market within the period that starts from 1995 until the end of 2001. They confirm the presence of a positive futures premium, which is in line with the findings by Gjølberg and Johnsen (2001). Botterud et al. (op. cit.) argue that the premium is partly explained by the difference in flexibility between demand and supply sides. Electricity producers are able to control their production on a short notice so they are able to take advantage of price fluctuations in the market. Demand side, on the other hand, has very limited ability to adjust quantities based on price. Risk-aversion leads to demand side having a higher incentive to hedge their positions in the futures market.

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[1] The study researched risk premium which is defined as futures premium with an opposite sign.

Mork (2006) studies the presence of futures premium in the Nordic electricity market in relation to the significant changes in the number of market participants between years 2000–2002. He finds that the significantly lowered futures premium between years 2000–2002 is attributable to the presence of more market participants. He suggests that the presence of the futures premium in a market is an invitation for speculators to enter such market.

In relatively more recent studies, Gjølberg and Brattested (2011) study the four and six weeks ahead futures contracts in the period of 1995–2008. They argue that the forecast error (futures premium) might in fact be a sign of market inefficiency. One way to investigate whether this error term is a result of risk is to study how it changes in relation with measures of risk in the market. For instance, the futures premium should be highest in winter due to higher spot prices and volatility compared to other seasons. Based on their analysis Gjølberg and Brattested (op. cit.) argue that the futures premium does not change significantly over seasons. No significant change over seasons and the magnitude of the error term (7–9% monthly) are the reasons that they believe pricing inefficiency should be taken into account.

In contrast with the findings of Gjølberg and Brattested (2011), a study by Lucia and Torro (2011) on weekly futures contracts traded at Nord Pool market from 1997 to 2007 shows that the futures premium is changing throughout the year. They find that the premium is greatest in winter and zero in summer.

In their latest work, Gjølberg and Smith (2016) study futures contracts with four weeks to maturity in the Nordic market. They conclude that after 2009 prices of futures became unbiased predictors of the expected spot prices in the delivery period. Gjølberg and Smith (op. cit.) assert that although this might suggest that the market turned efficient, unbiasedness is not a sufficient proof of the market efficiency.

3.3.2 Futures premium and measures of risk

Regarding the futures premium as a compensation for risk in electricity markets, one of the early studies by Bessembinder and Lemmon (2002) developed an equilibrium model for futures pricing. Their model illustrates the relationship between a hypothetical futures premium in a power market and dynamics of risk-averse producers and retailers. In such market retailers buy electricity from producers at wholesale prices and sell it to consumers at retail prices. Both retailers and producers are exposed to risks related to their revenues and costs of inputs, which leads to them hedging their expected profits using futures contracts.

Prices of the futures contracts are determined by a balance between hedging pressure from both sides. Bessembinder and Lemmon (op. cit.) argue that the revenue risk of the producers and the purchasing costs risk of the retailers are offsetting each other and have no effect on the futures premium as they are diversified within the system. Therefore, the futures premium is determined by the relative magnitude of retailers' revenue risk and producers' production cost risk.

Their model predicts that the variance of spot prices in the delivery period has a negative effect on the futures premium. Bessembinder and Lemmon (op. cit.) explain it by wholesale prices being positively correlated with the power demand in the market. In cases of high and normally distributed demand, the market expects high wholesale prices. High demand means that more power quantities are sold by the retailers. In such case the variance of wholesale prices, on average, make the revenues of the retailers positively exposed to the risk. This leads the risk-averse retailers to sell more futures contracts to create an offsetting exposure to eliminate the risk. It results in a downward bias in the prices of futures. Another prediction of the model is a positive relationship between skewness of the spot prices in the delivery period and the futures premium. High demand relative to production capacity shapes the distribution of the spot prices positively skewed. Positive skewness in the distribution of the expected spot prices makes potential upward spikes more probable. Short selling of the futures contracts in this case can incur huge losses. The risk of such incidents lowers willingness to take short positions which results into higher prices of the futures contracts.

Longstaff and Wang (2004) conducted a study in PJM (Pennsylvania, New Jersey and Maryland) day ahead futures market to find a link between forward prices and the measures of risk that market participants face. This was an attempt to prove that the futures premium exists in the market as a compensation for the risk that market participants are bearing. They found that the futures premium on average is positive but the sign of the premium varies, ranging from a negative value to a positive one. In addition, the futures premium in their study is negatively related to spot price variance and positively related to spot price skewness, which provides support for equilibrium model developed by Bessembinder and Lemmon (2002). Longstaff and Wang (op. cit.) argue that the futures premium is time-varying because the variance in the futures prices is usually less than the variance in the expected future spot prices. In the same context, Douglas and Popova (2008) add a variable representing gas storage to the Bessembinder and Lemmon (2002) model as another risk factor in the market. Their results in PJM market regarding the variance and the skewness of spot prices are also in line with the model’s predictions. They also found that the gas storage has a significant relationship with the futures premium.

Another study by Redl et al. (2009) developed an augmented version of Bessembinder and Lemmon (2002) model. In addition to the variance and skewness of spot prices as measures of risk, they add consumption and generation variables to the model. Their results show a positive and significant relationship of the futures premium with the skewness, while the coefficients for all the other variables were insignificant. They argue that inefficiencies in the market cannot be ruled out while further research is needed to clarify this.

Botterud et al. (2010) studied 11 years of spot and futures prices in the Nordic electricity market from 1996 to 2006. Again, their findings confirmed the presence of a positive futures[2] premium in the market. However, this time they augmented the model of Bessembinder and Lemmon (2002) to investigate the relationship between the futures premium and measures of risk in the market. The variables they included in their model were water reservoir level, deviations from average inflows and consumption, average spot prices, variance and skewness of the spot prices. As predicted, they found that the futures premium has a positive relationship with the water reservoir level, the deviation from average inflow and the average spot prices. They also found a negative relationship with the deviation from the average consumption even though they predicted that this relationship should be positive. Finally, the coefficients for the skewness and the variance of spot prices were insignificant which contradicted the predictions of the original model by Bessembinder and Lemmon (2002).

The most recent study by Weron and Zator (2014) is an effort to resolve some econometrics setup weaknesses and flaws in argumentation in the study conducted by Botterud et al. (2010). After separating seasonal and stochastic parts of the variable representing water reservoir level, Weron and Zator (op. cit.) find that the stochastic part is negatively related to the futures[3] premium, which contradicts the findings of Botterud et al. (op. cit.). The results regarding the other variables were similar. Finally, they conclude that their results cannot confirm with certainty whether futures premium is a result of risk or market inefficiency.

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[2] The study researched risk premium which is defined as futures premium with an opposite sign.

[3] The study researched risk premium which is defined as futures premium with an opposite sign.

4. Data

This section describes the data that is used throughout the study. Explanation of how variables are formed is followed by their descriptive statistics. Furthermore, properties of the variables and their implications on the methodology of the paper are discussed.

4.1 Description of variables

Upon contact with Nord Pool AS, we managed to gain access to the vast Nord Pool Spot database. We extracted system hourly spot prices in ELSPOT market as well as average weekly and monthly water reservoir level from the database. The spot price in the delivery period (variable S_T) is calculated as the average of the system hourly spot prices for the entire delivery week, that is 168 hours, or month, which is 720/744 hours. Reservoir level variable is constructed as a percentage of reservoir's total capacity. The number includes water reservoir levels in Norway, Sweden and Finland as these numbers are reported by Nord Pool Spot (2016).

Prices for weekly and monthly futures were collected through Bloomberg Terminal that provides historical database for NASDAQ commodities. The prices for the weekly contracts started being registered in January 2009 while the prices for the monthly futures are available from September 2003. Following the approach of Botterud et al. (2010), the closing price on the last trading day is used to represent the futures prices in trading period, $F_{t,T}$. For the weekly contracts the closing prices on Friday are extracted because no trading is done during the weekends. For the monthly contracts, futures prices are the closing price on last working day of each month.

Other studies such as Gjølberg and Brattested (2011), Gjølberg and Smith (2016) have a different approach regarding the variable representing the price of futures. They use the closing price of the futures contracts on the first day of the trading period that are settled against the average spot price of the subsequent delivery period. This increases the length of the time difference between the closing futures price and the following average spot price. Consequently, it is expected that our approach results in a better forecasting performance for the short-term futures contracts (1–2 weeks ahead) due to shorter time period between the futures price and the subsequent average spot price compared to the second approach.

Table 1 presents the obtained data sample and its statistical description. Mean and median of the futures prices seem to be higher than for the spot prices during the delivery period. These differences tend to increase with longer time to maturity.

Table 1. Sample descriptive statistics for the electricity spot and futures prices and water reservoir levels

	Item	Obs.	Mean	Median	Standard deviation	Minimum	Maximum
Weekly futures							
	Spot(W)	369	36.34	34.76	13.57	7.95	88.64
	F(W+1)	369	36.59	34.87	13.75	8.10	91.86
	F(W+2)	368	36.77	35.25	13.41	9.75	94.00
	F(W+3)	367	36.97	35.30	12.87	10.10	92.50
	F(W+4)	366	36.99	35.62	12.49	10.00	88.75
	F(W+5)	365	37.16	35.75	12.22	10.50	87.00
	F(W+6)	364	37.49	35.64	12.33	10.25	84.80
	Res(W)	369	60.26	65.75	20.33	16.50	91.40
Monthly futures							
	Spot(M)	147	36.19	33.60	12.45	9.55	81.65
	F(M+1)	147	37.18	34.35	12.70	11.40	90.77
	F(M+2)	146	38.41	35.92	12.19	14.70	85.10
	F(M+3)	145	39.10	36.68	11.89	19.21	78.05
	F(M+4)	144	39.57	37.73	12.02	19.88	76.25
	F(M+5)	143	39.91	37.80	11.72	19.40	77.50
	F(M+6)	142	39.65	37.94	11.78	18.19	76.43
	Res(M)	147	60.81	64.03	19.38	19.56	89.60

Notes: All prices are in euros while reservoir level is expressed a as percentage of reservoirs' total capacity. Spot(W) refers to the average spot price during delivery week, F(W+1) – the price of 1 week ahead futures, Res(M) – the average reservoir level during the delivery month. Other variables are interpreted accordingly. Adapted from Nord Pool Spot, 2016; Bloomberg (2016).

Following the conventional approach in working with electricity prices, the spot and futures prices are transformed into natural logarithm (log) of the market prices. We are able to do this because our sample uses prices that are averaged over a week/month, thus no negative values are present[4]. An explanation for this transformation relates to the positively skewed distribution of the electricity prices. As mentioned before, electricity markets are usually characterized as highly volatile compared to other commodity markets with occasional

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[4] Natural logarithm of a negative value is not mathematically defined.

upward spikes due to the non-storability of electricity. Taking log of the prices dampens the outliers (spikes) and makes the price distribution more symmetric, which allows obtaining more robust results (Weron, 2009).

Additional variables are necessary to test properties of the futures premium and relationship with measures of risk. These variables are not readily available; thus, they had to be generated based on the data obtained from Nord Pool Spot (2016) and Bloomberg (2016). For each of the weekly and monthly futures contracts, that are proven to have significant premium, the variable futures premium is created as the difference between logs of futures and spot prices. Skewness of the spot prices is calculated as daily sample skewness of the spot prices during the delivery period. Lastly, the measure of variance of the spot prices throughout the delivery period is constructed by calculating daily sample variance. Log of this variable is taken to transform its positively skewed distribution into normal.

Table 2. Sample descriptive statistics for the futures premium, variance and skewness of the spot prices

	Item	Obs.	Mean	Median	Standard deviation	Minimum	Maximum
Weekly futures							
	FP(W+5)	365	0.04	0.04	0.23	-0.77	1.57
	FP(W+6)	364	0.05	0.04	0.23	-0.69	1.56
	Var(W)	365	16.97	4.35	53.20	0.04	594.56
	Skew(W)	365	-0.30	-0.36	0.88	-2.30	2.31
Monthly futures							
	FP(M+2)	146	0.07	0.07	0.20	-0.53	0.59
	FP(M+3)	145	0.09	0.11	0.25	-0.64	0.84
	FP(M+4)	144	0.10	0.09	0.29	-0.56	0.99
	FP(M+5)	143	0.11	0.09	0.31	-0.70	0.98
	FP(M+6)	142	0.10	0.09	0.33	-0.59	1.06
	Var(M)	146	24.07	11.61	45.06	0.57	367.97
	Skew(M)	146	-0.06	-0.15	0.92	-1.89	2.78

Notes: FP(W+1) refers to the premium of 1 weeks ahead futures contract, Var(M) and Skew(M) – variance and skewness of the spot prices during delivery month. Other variables are interpreted accordingly. Adapted from Nord Pool Spot, 2016; Bloomberg (2016).

4.2 Properties of the data series

In this section, we discuss important statistical properties of all of the variables used. These properties are specifically relevant for the methodology section as they are taken into consideration when choosing econometric tools to ensure the robustness of the results.

4.2.1 Stationarity

By definition, a stationary process has constant mean and variance, while covariance between any two lags in the series is dependent only on the distance between them (Wooldridge, 2013). When working with non-stationary data, there is always a risk of getting statistically significant relationship between variables that is not present in reality. Hence, before the first step to estimate the model, Augmented Dickey-Fuller (ADF) test is used to examine the data series for unit roots. To choose the appropriate number of lags, Bayesian Information Criterion (BIC) is used due to its superiority to AIC criterion in samples larger than 60 observations (Liew, 2004). Any trends, breaks, seasonal or monthly effects are taken away before testing for stationarity to prevent them from interfering with the results.

Both weekly and monthly futures contracts and spot prices have downward trends and show monthly or seasonal effects. A break exists on approximately January 2011 for both of the series that changes the slope of the trend (Figures 5 and 6). As a result, the futures and the spot prices are regressed on trend variable, monthly/seasonal and break dummy variables and an interaction term between break dummy and the trend. It results in all these variables being significant as shown in Tables 8 and 9 in the Appendices section. The residuals of the regression deliver the de-trended price series without seasonal/monthly, trend and break effects that are illustrated in Figures 8 and 9.

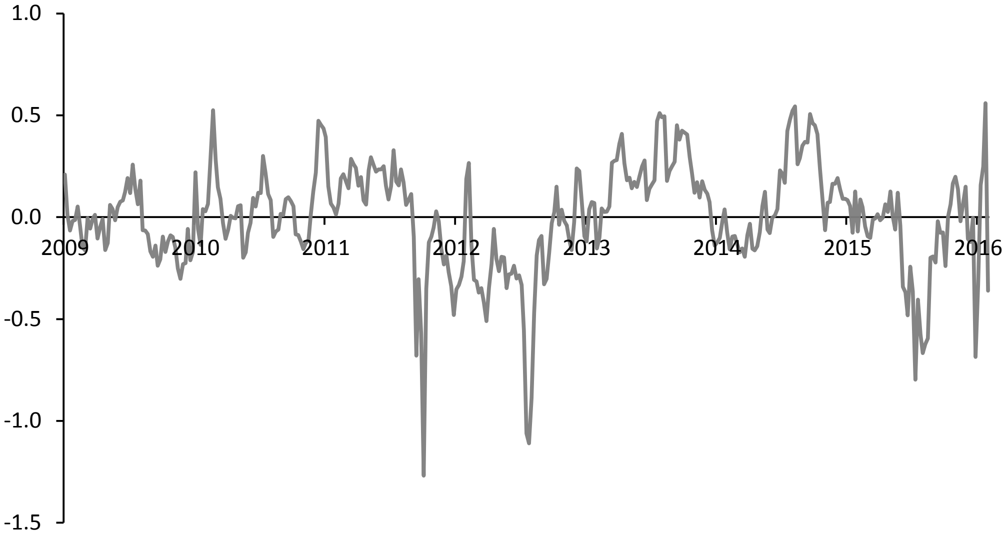

Figure 8. Log of de-trended weekly spot price without monthly effects and breaks (January 2009 – January 2016). Adapted from Nord Pool Spot, 2016.

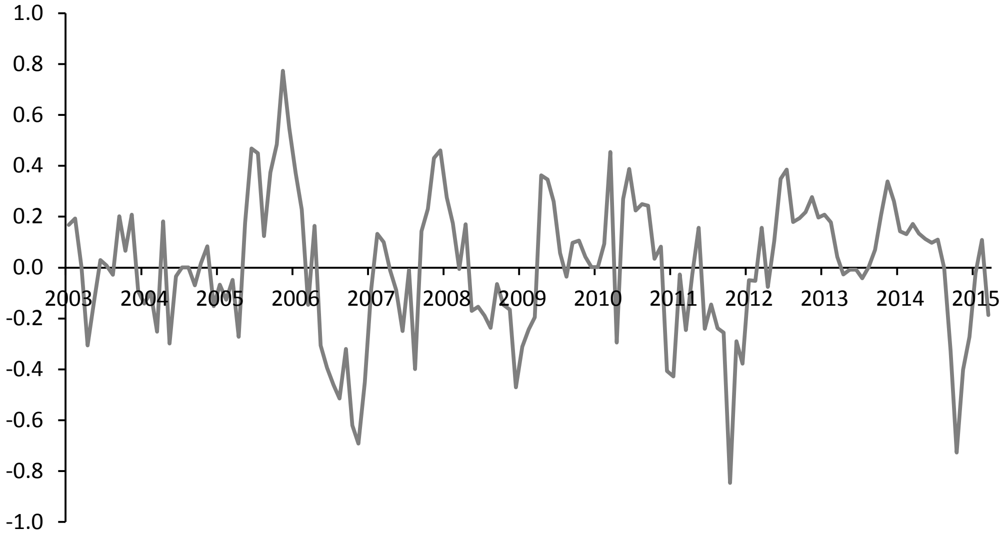

Figure 9. Log of de-trended monthly spot price without seasonal effects and breaks (October 2003 – December 2015). Adapted from Nord Pool Spot, 2016.

Visually observing the data series, we chose the appropriate form of the ADF test without drift term and trend. Based on BIC, four lags are selected in the test to control for the autocorrelation in the error term. The results of the ADF tests are presented in Table 3. The test statistics values imply that the null hypothesis of random walk is rejected for both the futures and the spot prices. Therefore, the series are considered stationary. All the other variables proved to be stationary using the same approach.

Table 3. Results of the ADF test for stationarity of variables

Variable	N	Lags	ADF	1% Critical value	Variable	N	Lags	ADF	1% Critical value
Spot(W)	367	1	-5.78	-2.58	FP(W+5)	359	5	-6.39	-3.45
F(W+1)	367	1	-5.56	-2.58	FP(W+6)	361	2	-7.76	-3.45
F(W+2)	366	1	-4.88	-2.58	Var(W)	367	1	-9.93	-3.45
F(W+3)	365	1	-4.25	-2.58	Skew(W)	366	2	-8.02	-3.45
F(W+4)	364	1	-3.83	-2.58	Res(W)	364	4	-6.13	-3.45
F(W+5)	363	1	-3.72	-2.58	FP(M+2)	144	1	-7.40	-3.50
F(W+6)	362	1	-3.88	-2.58	FP(M+3)	142	2	-6.38	-3.50
Spot(M)	145	1	-4.44	-2.59	FP(M+4)	140	3	-5.46	-3.50
F(M+1)	145	1	-4.32	-2.59	FP(M+5)	141	1	-4.99	-3.50
F(M+2)	144	1	-4.10	-2.59	FP(M+6)	140	1	-4.39	-3.50
F(M+3)	143	1	-4.22	-2.59	Var(M)	144	1	-6.01	-3.50
F(M+4)	142	1	-4.23	-2.59	Skew(M)	145	1	-6.42	-2.59
F(M+5)	141	1	-3.95	-2.59	Res(M)	144	2	-7.49	-3.50
F(M+6)	140	1	-3.72	-2.59					

Notes: Spot(W) refers to the average spot price during delivery week, F(W+1) – the price of one week ahead futures, Res(M) – the average reservoir level during the month, FP(W+1) – the premium of 1 week ahead futures contract, Var(W) and Skew(W) – variance and skewness of the spot prices during delivery week. Other variables are interpreted equivalently. Adapted from Nord Pool Spot, 2016; Bloomberg (2016).

4.2.2 Autocorrelation

In presence of autocorrelation, standard errors and test statistics are not valid when using OLS method (Wooldridge, 2013). Since this paper deals with time series data, it is necessary to check the data set for this property.

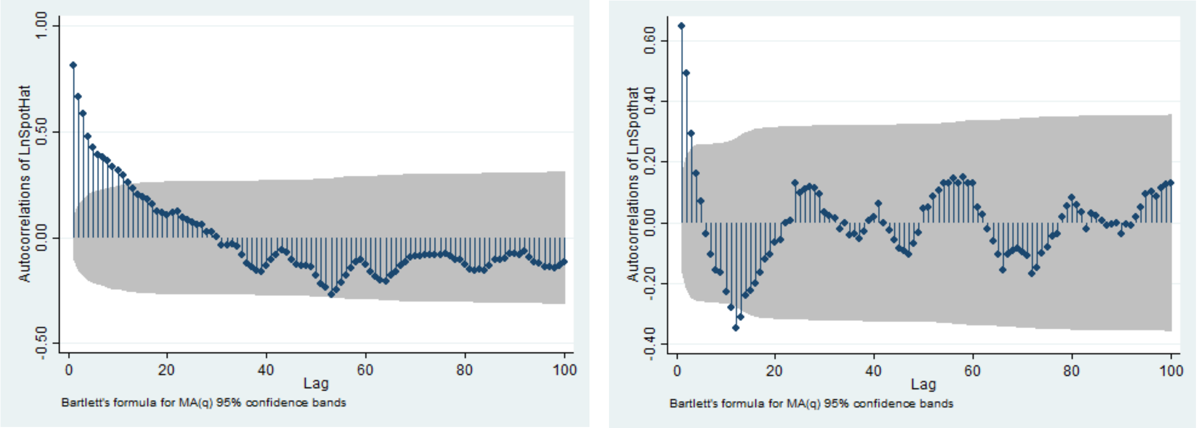

Figure 10. Correlogram for weekly (on the left) and monthly (right) spot prices without monthly/seasonal, trend or break effects. Adapted from Nord Pool Spot, 2016.

The plots above are graphs of the autocorrelation for the first hundred lags of the variables created using ac command on Stata (Stata, 2013). The statistical software calculates correlation of a variable with each of its lagged values using Bartlett's formula and illustrates it as spikes on the correlogram. The shaded area represents a threshold where the relationship is significant at 95% level. The peaks outside the shaded area indicate that spot prices are autocorrelated. For example, the monthly spot prices at each point in time have correlation with their values from previous year (12 months ago) because the peak for lag twelve is outside of the shaded area. Similarly, the futures premium calculated for all of the weekly and monthly futures contracts with different maturities have autocorrelation.

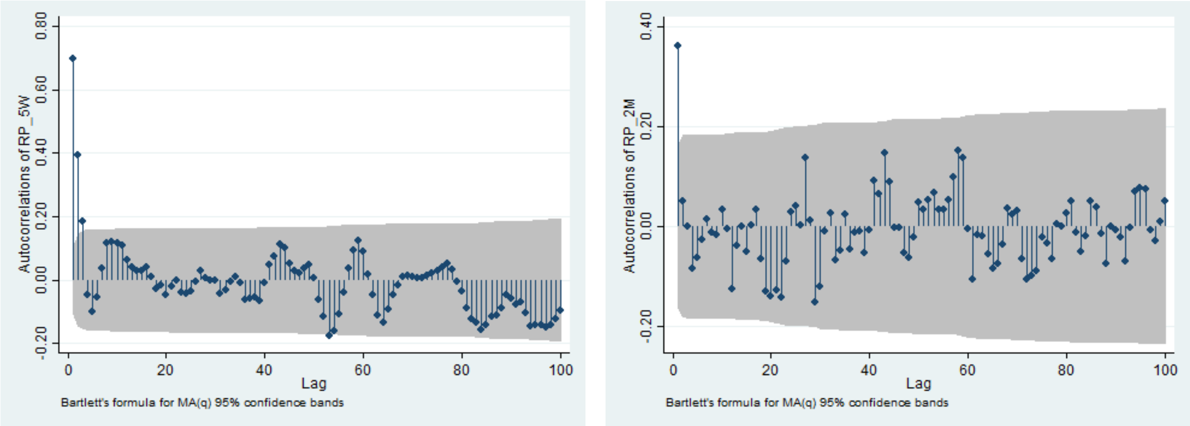

Figure 11. Correlogram for the futures premium of 5 weeks ahead (on the left) and 2 months ahead futures contracts. Adapted from Nord Pool Spot, 2016.

4.2.3 Heteroskedasticity

Heteroskedasticity exists in a regression when variance of an error term changes depending on an explanatory variable. While the estimation of the coefficients might not be biased, heteroskedasticity invalidates the estimated standard errors and respectively test statistics (Wooldridge, 2013). Electricity prices are positively skewed and heteroskedastic with high/low volatility when the prices are high/low (Kaminski, 1997; Routledge et al., 1998).

Bruesch-Pagan test is employed to test for heteroscedasticity. It is performed by regressing the squared residuals on the explanatory variables. The null hypothesis is that the error terms are homoscedastic or independent of the explanatory variables. Rejecting the null hypothesis implies that the variance of the error term is changing depending on the explanatory variables indicating presence of heteroskedasticity (Wooldridge, 2013). In later sections this test is used to check for the robustness of the regressions results.

5. Methodology

This chapter presents the methodology used to approach the research question, followed by an explanation of all the tests, models and econometrics techniques used throughout the study. The first part of the methodology aims to identify whether futures premium is present in each of the contract chosen for analysis. Then properties of the futures premium are investigated. Lastly, the relationship between the futures prices and measures of economic risk is tested to find out whether the futures premium exists as a compensation for risk or it is a bias present due to market inefficiencies.

5.1 Test for presence of futures premium

Futures premium is closely related to the forecasting performance of the futures contracts. If significant time-varying futures premium is present, the futures prices are not reliable predictors of the future spot prices (Fama & French, 1987). To identify whether significant futures premium is present in the futures contracts in the Nordic market, forecasting performance of each contract is examined. There are two main approaches to test the forecasting performance that are commonly found in the literature.

The first approach is to regress the changes in the spot prices (or log returns) on the lagged basis ($F_{t,\,T} - S_t$) and test for the significance of the coefficients – see Fama and French (1987), Gjølberg and Brattested (2011). Model (1) captures the dynamics of the market by explaining the changes in the spot prices until delivery based on the difference between today's futures and spot prices (defined as basis).

$$\boldsymbol{ln(S_T) - ln(S_t) = a_0 + a_1\big(ln(F_{t,T}) - ln(S_t)\big) + \varepsilon_{t,T}} \qquad \textbf{(6)}$$

where time t represents trading period and time T – delivery period; $\boldsymbol{ln(S_T) - ln(S_t)}$ is the changes in the log of spot prices for the period starting from the trading period (time t) until the delivery period (time T). Relatively, $\boldsymbol{ln(F_{t,T}) - ln(S_t)}$ is the basis (based on log prices) on the last day of trading period (time t) and $\boldsymbol{\varepsilon_{t,T}}$ is the error term.

Another approach to test for forecasting ability of the futures contracts is to regress the spot prices on futures prices – see Frankel (1976), Modjtahedi and Movassagh (2005).

$$\boldsymbol{ln(S_T) = b_0 + b_1 ln(F_{t,T}) + u_{t,T}} \quad \textbf{(7)}$$

where $\boldsymbol{ln(S_T)}$ is a log of the realized spot price for the delivery period, $\boldsymbol{ln(F_{t,T})}$ is the closing price of the futures contracts on the last day of trading period t with delivery period at time T and $\boldsymbol{u_{t,T}}$ is the error term.

Based on the expectation hypothesis, the futures prices are unbiased predictors of the expected spot prices of the delivery period, if $\boldsymbol{a_1/b_1}$ in models (6)/(7) is not significantly different from unity and the intercept is not significantly different from zero. In a perfect market it is expected that today's futures prices reflect the expected future spot prices on the delivery period. If $\boldsymbol{a_1/b_1}$ is significantly different from unity, this would imply that there is a time-varying futures premium present in the market. In case of $\boldsymbol{a_1/b_1}$ equal to unity and intercept being anything other than zero, the absolute value of the intercept reflects the magnitude of the futures premium as it is the average difference between spot and futures price. In addition, in this case the futures premium is constant because as $\boldsymbol{a_1/b_1}$ is equal to unity, futures prices follow spot prices perfectly and the difference remains constant and equal to $\boldsymbol{a_0/b_0}$.

In his study about testing for forward's unbiasedness, Maynard (2003) criticizes model (6). He argues that researchers used the differenced model (6) to deal with non-stationary data series until a proper econometrics tool was developed to work with non-stationary data. Recently developed cointegration technique allows working with non-stationary data. Hence, this turned attention of researchers to use model (7) for measuring the forecasting performance. Modjtahedi and Movassagh (2005) add that the model (6) is more suited to test market-timing[5] property of futures contracts as it regresses change in spot prices on basis, while the model (7) is generally used to test unbiasedness of futures contracts in estimating future spot prices. Since our aim is to identify whether significant futures premium exists, the model (7) is used for this paper.

5.1.1 Estimation of the model

Before the estimation, we need to take into account that trends, breaks, seasonal effects in the series of prices can affect the values of coefficients (Weron & Zator, 2014). In addition

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[5] Ability to predict whether spot prices will increase or go down.

to stochastic components, variables used in estimation of the model (7) have seasonal/monthly components as well as breaks and trends. We are not interested in capturing the effects of seasonality or trends because they can also reflect the seasonal behavior of omitted variables in the model. The stochastic components are less likely to be correlated with these variables. By taking away seasonality, trends and breaks, we are more likely to obtain the pure and robust relationship between the two series of prices.

Later on, it is needed to make sure that the stochastic component of the variables is stationary. Based on the results from the ADF test indicating the stationarity condition of the variables, we can trust the OLS regression results as long as the estimated model's residuals are checked for autocorrelation and possible heteroskedasticity. However, both futures and spot prices have heteroskedastic and autocorrelation properties. In order to obtain robust standard errors in our estimation, we use Newey-West estimator that is commonly applied in similar cases to efficiently overcome the effect of autocorrelation and heteroskedasticity in the error term (Newey, 1985).

Electricity prices are known to have volatility clustering properties, meaning that periods of large changes in prices are more likely to be followed by large changes in prices and vice-versa. This implies that the variance of the error terms in the estimated model is a function of variances of previous periods' error terms. One of the most popular approaches to model the conditional volatility is GARCH[6] model, which assumes the current variance of the error term to be a function of the realized error terms in the previous periods (Escribano et al., 2011). However, the volatility clustering in the error term does not violate any of the assumptions[7] for the best linear unbiased estimator of the coefficients in a regression. Since we are interested only in the regression coefficients and their standard errors rather than modeling and forecasting the volatilities, using the GARCH model and its extensions is outside the scope of this study.

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[6] Generalized autoregressive conditional heteroskedasticity.

[7] 1) Linearity in parameters; 2) expected value of the error term is zero for all observations; 3) conditional variance of the error term is constant for any value of explanatory variable and over time 4) error terms are not correlated 5) error term is uncorrelated with the explanatory variables; 6) no exact linear relationships among multiple independent variables (Wooldridge, 2013).

5.1.2 Newey-West estimator

Newey-West estimator is a method of estimation developed by Newey and West to compute heteroscedasticity and autocorrelation consistent standard errors. These standard errors are calculated conditional on a choice of maximum lags, which is decided based BIC criterion. A Newey-West estimator with zero lags is the same as OLS estimator. Newey-West standard errors in a time series context are robust to both autocorrelation and heteroscedasticity (Wooldridge, 2013). The statistical test for significance of the estimated coefficients is the t-test. Based on an assumption that estimated variables are normally distributed, this test uses their estimated standard deviation to make inference about their statistical significance. In our study, we apply a two-sided t-test for the significance of the estimated variables.

5.2 Magnitude and sign of the futures premium

Previous literature on the Nordic market shows that on average futures prices overshoot the following spot prices. In order to test for this phenomenon, we calculate the average futures premium, or the difference between the futures and the expected future spot prices, over the period of study for all the contracts. Based on the expectation hypothesis, futures premium is defined as:

$$\boldsymbol{FP_{t,T} = F_{t,T} - E_t}[\boldsymbol{S_T}] \qquad \textbf{(8)}$$

where $\boldsymbol{FP_{t,T}}$ is the futures premium for contracts bought at time t that mature in time T; $\boldsymbol{F_{t,T}}$ is the price of the futures contracts at time t; and $\boldsymbol{E_t}[\boldsymbol{S_T}]$ is an expectation at trading period t of the spot price during the delivery period T. Estimation of $E_t[S_T]$ requires careful modeling of price movements and various assumptions have to be made regarding the data available for market participants at time t. Usually S_T, or the realized spot price, is used in the literature instead of $E_t[S_T]$ to estimate the futures premium ex-post (Weron & Zator, 2014; Botterud et al., 2010). If we presume that the market is rational, then $S_T = E_t[S_T] + \varepsilon_T$, where ε_T is a white noise. In this case, the realized spot prices become a good approximation of the expected spot prices at time T.

Now if we consider the futures premium as a continuously compounded rate of return, then the futures price would be:

$$\boldsymbol{F_{t,T} = S_T e^{\pi_{t,T}}} \tag{9}$$

where $\boldsymbol{F_{t,T}}$ is the price of the futures contracts traded at time t with delivery period at time T; $\boldsymbol{S_T}$ is the spot price during delivery period T; and $\boldsymbol{\pi_{t,T}}$ is the continuously compounded futures premium.

Then $\boldsymbol{\pi_{t,T}}$ can be presented:

$$\boldsymbol{\pi_{t,T} = \ln \frac{F_{t,T}}{S_T}} \tag{10}$$

Or

$$\boldsymbol{\pi_{t,T} = \ln F_{t,T} - \ln S_T} \tag{11}$$

After computing futures premium, we investigate its properties. Mean, variance and percentage of cases when the premium is positive are calculated. Testing for the presence of seasonality in the futures premium is important because seasonality can be an indication of rational variation in futures premium. As a result, we regress the calculated futures premium as the dependent variable on seasonal dummies to check if it varies significantly through seasons.

$$\boldsymbol{\pi_{t,T} = \beta_0 + \sum_{i=1}^{3} \beta_i D_i + e_{i,T}} \tag{12}$$

where $\boldsymbol{\pi_{t,T}}$ is the continuously compounded futures premium; and $\boldsymbol{D_i}$ are dummy variables for different seasons.

Before estimating the model (12), the futures premium variables are inspected and found to be stationary. As futures premium is found to be autocorrelated, regression with Newey-West standard errors is used.

5.3 Link between futures premium and risk factors

The last part of the methodology is aimed at finding the relationship between futures premium and the measures of economic risk. Bessembinder & Lemmon (2002) developed a model (13), which provides a good insight of potential risk elements present in an electricity market. They concluded that variance and skewness of future spot prices during delivery period are the main two factors that determine the futures premium.

$$\boldsymbol{\pi_{t,T} = c_0 + c_1 Var[S_T] + c_2 Skew[S_T] + \nu_{t,T}} \quad \textbf{(13)}$$

where time t represents the trading period and time T – delivery period; dependent variable $\pi_{t,T}$ is the continuously compounded futures premium, while the independent variables are daily variance and skewness of the spot prices for the delivery period T.

The model (13) predicts that the futures premium should be negatively affected by the variance of the spot prices (c_1<0) and positively by the skewness of the spot prices (c_2>0). The model assumes no irrationality and inefficiencies in the market; therefore, one can apply this model to discover to what extent futures premiums reflect the fundamental sources of risk faced by market participants. Although this model is simplified and assumes that outside speculators have no role in determining the futures prices in the market, its predictions has been tested and supported by other studies.

As discussed in the theory and previous empirical findings section, Bessembinder and Lemmon (2002) also indicated that producers are exposed to the production cost risk, which should affect futures premium. Although in their original model they did not include a variable to reflect such risk, we strongly believe that the model can be augmented for the Nordic electricity market by adding water reservoir level variable.

$$\boldsymbol{\pi_{t,T} = d_0 + d_1 Var[S_T] + d_2 Skew[S_T] + d_3 Reservoirlevel + z_{t,T}} \quad \textbf{(14)}$$

High share of hydropower production gives a unique characteristic to the Nordic electricity market that does not exist in other electricity markets. Water reservoirs function like batteries that can hold and release electricity at any time, which makes them similar to inventories in other storable commodity markets. Based on the theory of storage, the futures premium in the Nordic electricity market must reflect the costs of carry and the convenience yield related to the water reservoir. Botterud et al. (2010) show that when the reservoir level is low, the costs of storage are low while the convenience yield is high since probability to have high spot prices in the market is high. On contrast when the water reservoir level is highest, the costs of storage are highest while the convenience yield is at its lowest. This is due to the financial risks of water overflow and spillage that could otherwise be used to produce electricity if the reservoir was not full. This implies that the futures prices are biased upwards compared to the expected spot prices when the water reservoir level is high.

Therefore a positive relationship is expected between the futures premium and the reservoir level (d3>0)

Inflow is another variable that has been used in the literature to explain the production risk. However, theoretical explanation of the relationship between the futures premium and inflow is based on inflow affecting the reservoir level. Since inflow is not directly affecting the futures premium, there is no necessity to add it in the model when its effect is already captured by the reservoir level.

5.3.1 Estimation of the model

As shown in Figures 8 and 9 in the Appendices section, reservoir level, variance, and skewness variables exhibit seasonal trends. To avoid the effects of omitted variables on the estimated coefficients, we again take away seasonal components. Then, natural logarithm of the standard deviation is used to transform its positively skewed distribution to normal.

All of the variables in model (14) are stationary time series, thus they require no additional transformations. However, the weekly and monthly futures contracts are autocorrelated. In order to obtain robust standard errors, we use Newey-West method to estimate the coefficients of the model (14). The value of continuously compounded futures premium ($\pi_{t,T}$) is regressed on the daily skewness and the log of daily variance of the spot prices and the average water reservoir level during the delivery period. The estimation is repeated for each of the futures contacts that are proven to have significant premium.

6. Results and discussion

This section presents the findings of the study. First, contracts with significant futures premium are identified. Then these particular contracts are used to analyze the properties of the futures premium. Third, the link between futures premium and the measures of risk is established. Finally, the results are discussed in light of findings of other authors.

6.1 Presence of futures premium

Table 4 summarizes the results from the regression analysis of futures and spot prices to examine the presence of futures premium in the market (model 7). Coefficients for prices of 1–4 weeks ahead contracts are not significantly different from 1. This implies that the futures prices follow the expected future spot prices in the market and therefore there is no time-varying futures premium in these contracts. Even though the futures prices follow the subsequent spot prices, there might be a difference between their values that is constant over time. In such case the average difference of two variables is reflected in the value of the constant term. However, the constant term is not significantly different from zero for 1–4 weeks ahead futures. This indicates that there is neither time-varying nor constant futures premium for these futures contracts with respect to the expected future spot prices for the delivery period. Therefore, prices of 1–4 weeks ahead future contracts are unbiased estimators of the expected future spot price.

Coefficients for 5 and 6 weeks ahead futures contracts are different from 1 at 10% significance level, indicating the presence of a time-varying premium in the futures prices that should be investigated further.

Situation with the monthly futures is a bit different. Only 1 month ahead futures contracts have coefficient that is not different from 1 and the constant term that is not different from 0 and is therefore unbiased. Coefficients are different from 1 at 5% significance level for 2 and 3 months ahead futures and at 1% for contracts with maturities of 4–6 months. Coefficients go as low as 0.1769 for 6 months ahead futures suggesting a huge bias in prices.

Table 4. Forecasting performance of the futures contracts

	Time to maturity	Lags	Obs.	Constant	Futures price	R^2
Delivery period - 1 week						
	1 week	1	369	-0.0022	0.9766	0.8490
				(0.0054)	(0.0387)	
	2 weeks	2	368	-0.0030	0.9213	0.6346
				(0.0101)	(0.0600)	
	3 weeks	2	367	-0.0028	0.9105	0.5110
				(0.0132)	(0.0816)	
	4 weeks	3	366	-0.0025	0.8649	0.4077
				(0.0161)	(0.0854)	
	5 weeks	4	365	-0.0027	0.8196*	0.3304
				(0.0185)	(0.0963)	
	6 weeks	2	364	-0.0028	0.8234*	0.3233
				(0.0168)	(0.0905)	
Delivery period - 1 month						
	1 month	1	147	0.0000	0.8962	0.6785
				(0.0118)	(0.0666)	
	2 months	2	146	-0.0011	0.7897**	0.4269
				(0.0198)	(0.1023)	
	3 months	2	145	-0.0025	0.7033**	0.2887
				(0.0260)	(0.1365)	
	4 months	1	144	-0.0025	0.4646***	0.1269
				(0.0267)	(0.1362)	
	5 months	2	143	-0.0004	0.3069***	0.0502
				(0.0324)	(0.1724)	
	6 months	1	142	0.0006	0.1769***	0.0186
				(0.0290)	(0.1472)	

Notes: Regression (model 7) with Newey-West standard errors (in parenthesis). Dependent variable - expected spot price during delivery period. Independent variable – price of the futures contract during trading period. Number of lags is selected by using Bayesian information criterion. *Coefficient is different from 1 at 10% significance level; ** - at 5 %; and *** - at 1%.

Taking all the weekly and monthly regressions into consideration, there is a clear pattern that values of the estimated coefficients decrease and standard errors increase with longer time to maturity. In addition, the decline in the forecasting ability of the future prices is much steeper for the monthly compared to the weekly contracts.

6.2 Properties of the futures premium

Regression analysis identified that time-varying futures premium is present in 5–6 weeks and 2–6 months ahead futures contracts. Therefore, these particular contracts and their properties are further analyzed.

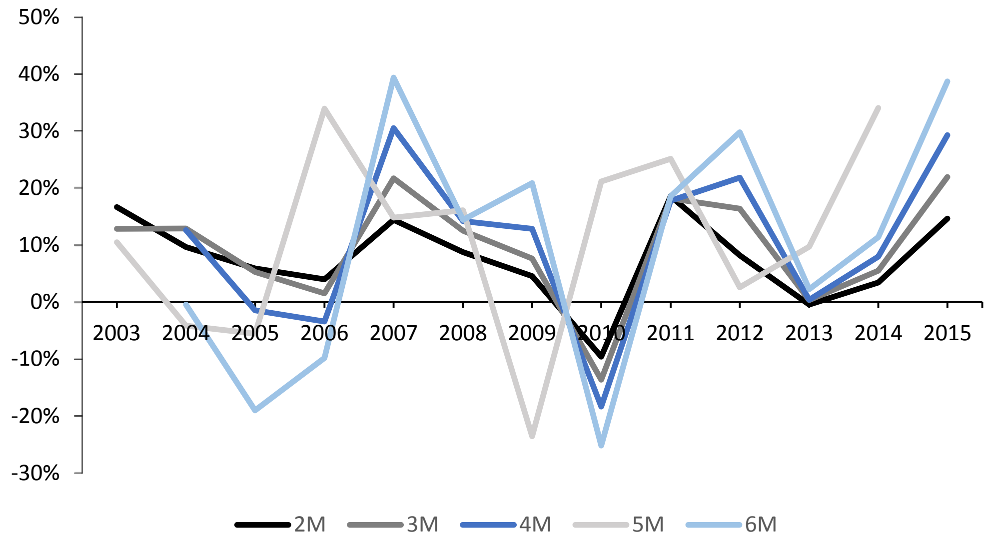

Figure 12. Average futures premium for 2–6 months ahead contracts over the years (October 2003 – December 2015). Adapted from Nord Pool Spot (2016).

Figure 12, illustrates the evolution of the futures premium throughout the years. Average futures premiums can be positive or negative in different years. However, further analysis reveals that the futures premium on average is positive for all the contracts. The magnitude of the premium ranges from 4.33% to 11.41% depending on time to maturity. The standard deviation of the futures premium is from 20.37 to 33.17 % for different contracts indicating very large variations in the premiums over time. In 59.59%–64.34% of the cases the premiums are found to be positive. The annualized futures premium for all of the contracts is calculated for comparison purposes. We find that the annualized continuously compounded premium is lowest at 23% for 6 months ahead contracts and highest at 56% for 2 months ahead contracts. Such findings indicate that a strategy of systematically selling the futures for a whole year would yield a significant positive return.

Table 5. Properties of the futures premium in the Nord Pool futures market

	Time to maturity	Futures premium (FP)	Standard deviation of FP	Annualized FP	Probability of positive FP
Delivery period - 1 week					
	5 weeks	4.33%	22.80%	50.01%	60.00%
	6 weeks	5.27%	22.75%	49.84%	60.71%
Delivery period - 1 month					
	2 months	6.96%	20.37%	55.71%	59.59%
	3 months	9.21%	24.66%	44.22%	65.52%
	4 months	10.35%	29.00%	35.47%	64.58%
	5 months	11.41%	31.34%	30.43%	64.34%
	6 months	10.40%	33.17%	22.69%	61.27%

The table 6 below reports the results of regressing futures premium on seasonal dummies. Insignificance of the dummy coefficients shows that the futures premium neither for the weekly nor for the monthly futures contracts varies significantly by seasons.

Table 6. Test for seasonality in the futures premium

	Time to maturity	Lags	Obs.	Constant	Spring	Summer	Autumn	R^2
Delivery period - 1 week								
	5 weeks	5	365	0.0067	0.0205	0.0682	0.0581	0.0148
				(0.0423)	(0.0479)	(0.0595)	(0.0601)	
	6 weeks	2	364	0.0152	0.0269	0.0731	0.0499	0.0142
				(0.0384)	(0.0440)	(0.0543)	(0.0542)	
Delivery period - 1 month								
	2 months	1	146	0.1157**	-0.0863	-0.0440	-0.0550	0.0232
				(0.0487)	(0.0554)	(0.0633)	(0.0585)	
	3 months	2	145	0.1495**	-0.1042	-0.0701	-0.0567	0.0236
				(0.0685)	(0.0744)	(0.0884)	(0.0725)	
	4 months	3	144	0.1805**	-0.1126	-0.1136	-0.0820	0.0256
				(0.0837)	(0.0922)	(0.1095)	(0.0871)	
	5 months	1	143	0.1762***	-0.0603	-0.1147	-0.0792	0.0183
				(0.0651)	(0.0853)	(0.0937)	(0.0772)	
	6 months	1	142	0.1416**	-0.0213	-0.0701	-0.0645	0.0078
				(0.0687)	(0.0979)	(0.1009)	(0.0825)	

Notes: Regression (model 12) with Newey-West standard errors (in parenthesis). Dependent variable – futures premium. Independent variables – seasonal dummy variables. Number of lags is selected by using Bayesian information criterion. *Coefficient is different from 0 at 10% significance level; ** - at 5 %; and *** - at 1%.

6.3 Futures premium and risk factors

In order to explain the variations of the futures premium over time we developed the model (14) based on the well-known equilibrium model by Bessembinder and Lemmon (2002) to price the futures contracts in power markets. Variance and skewness of the spot prices and water reservoir level are the independent variables in the augmented model for the Nordic electricity market, chosen to capture the variations in the futures premium. Values of these variables represent the level of risk associated with producers' production cost and retailers' revenues. Table 7 below summarizes the results of the regressions.

Table 7. Regression of the futures premium on the measures of risk

	Time to maturity	Lags	Obs.	Constant	Variance	Skewness	Reservoir	R^2
Delivery period - 1 week								
	5 weeks	1	365	0.0434***	-0.0343**	0.0036	0.0066***	0.0909
				(0.0148)	(0.0139)	(0.0181)	(0.0019)	
	6 weeks	1	364	0.0530***	-0.0300**	0.0010	0.0072***	0.0915
				(0.0148)	(0.0136)	(0.0177)	(0.0019)	
Delivery period - 1 month								
	2 months	1	146	0.1001**	-0.0127	-0.0556***	0.0048***	0.1019
				(0.0438)	(0.0182)	(0.0197)	(0.0018)	
	3 months	1	145	0.1697***	-0.0322	-0.0215	0.0066***	0.0950
				(0.0558)	(0.0217)	(0.0244)	(0.0022)	
	4 months	1	144	0.1653**	-0.0259	-0.0349	0.0093***	0.1190
				(0.0641)	(0.0238)	(0.0282)	(0.0024)	
	5 months	1	143	0.1633**	-0.0218	-0.0061	0.0094***	0.0990
				(0.0723)	(0.0277)	(0.0318)	(0.0027)	
	6 months	1	142	0.0900	0.0033	-0.0176	0.0103***	0.0973
				(0.0841)	(0.0298)	(0.0333)	(0.0028)	

Notes: Regression (model 14) with Newey-West standard errors (in parenthesis). Dependent variable – futures premium. Independent variables – variance and skewness of the spot price and reservoir level during the delivery period. Number of lags used is 1 for all the regressions (selected using Bayesian information criterion). *Coefficient is different from 0 at 10% significance level; ** - at 5 %; and *** - at 1%.

The results show that reservoir level is the best measure in explaining the variation of the futures premium. Its coefficients are statistically significant at 1% in the regressions for all maturities. The relationship is positive in all the regressions. One standard deviation change in the de-seasonalized reservoir level variable (10.13 percentage point), results in 4.83–10.47 percentage point change in the premium depending on time to maturity.

The variance of the spot prices is found to have a negative effect on the futures premium in the 5 and 6 weeks ahead contracts. The relationship is statistically significant at 5%. However, a significant link was not present in the regressions involving the monthly contracts.

The skewness of the spot prices turned out to be insignificant in most of the regressions, with an exception of 2 months ahead contracts. In this particular contract we found a negative effect of the skewness on the futures premium. This coefficient is statistically significant at 1% level. However, the sign is the opposite than it is predicted by the literature.

6.4 Discussion

The findings of this paper indicate that no significant futures premium is present in the Nordic electricity market for shorter time to maturities futures, including 1–4 weeks ahead and 1 month ahead contracts. This is in line with the findings of Gjølberg and Smith-Meyer (2016) regarding the presence of the futures premium for one month ahead futures contracts over the same period. However, the presence of the futures premium is evident for 5–6 weeks ahead and 2–6 months ahead futures contracts. In addition, the ability of the futures prices to forecast the subsequent spot prices declines as the time to maturity extends. This indicates that the magnitude of the premium increases alongside the time to maturity.

The futures premium is positive about 60% of the time for all of the contracts showing that the futures prices usually overshoot the subsequent spot prices. The premium has no statistically significant variation through seasons or months. Clearly as the risk faced by market participants varies through seasons, absence of seasonal or monthly components in the futures premiums provide some indication that the variation in the premium might not be risk related. Seasonality, as a feature of the futures premium, is widely discussed in the literature. Our findings are in line with a study of Gjølberg and Brattested (2011) on the Nordic weekly futures during the period from 1995 until 2008. At the same time our results are in contrast with a study on Nordic weekly futures contracts by Torro and Lucia (2008). They found that during the period between 1997 and 2007 the premium varies significantly by seasons. It is zero in spring and summer, while being positive in fall and highest in winter. However, none of the studies are directly comparable as we investigate the seasonality of the futures premium for a different period that is more recent.

Arguably the most important aspect of the futures contracts in the Nordic market is the unreasonably large magnitude of the futures premium. We find that the range of the annualized continuously compounded rate of return for different contracts is 22–56%. This is substantially higher than a typical 5–8 % annual premium in a wide range of commodity markets (Gorton & Rouwenhorst, 2006). Previous studies on the Nordic futures contracts found results that are comparable to ours. Botterud et al. (2010) found 4.4% monthly return for 6 weeks ahead contracts during 1996–2006. Redl et al. (2009) performed a study for period between 2003 and 2008 and found 5% monthly return for 1 month ahead contracts. Gjølberg and Brattested (2011) found 7–9% monthly return for 1 month ahead contracts in 1995–2008. Finally, Smith Meyer and Gjølberg found 3.5 % monthly return for 1 month ahead contracts for period between 2003 and 2015. Consistent findings in support of the substantial futures premium for the Nordic electricity futures market raise the question about the presence of irrationality or inefficiency in the market.

In order to investigate further we explain the variations in the futures premium by the proposed risk measures in the equilibrium model by Bessembinder and Lemmon (2002) augmented with the water reservoir level that represents the production cost risk in the Nordic electricity market. Our findings indicate that participants in the Nordic electricity market reflect their expectations of the water reservoir level in the futures prices. The positive relationship between the water reservoir level and the futures premium can be explained by the theory of storage. High water reservoir level is associated with high cost of storage, high risk of water spillage and low convenience yield. As a result, an upward pressure for the futures prices exists as a producer requires a compensation for these costs. The same conclusion was achieved by Botterud et al. (2010) who studied the Nordic electricity market from 1996 to 2006.

We achieved mixed results regarding the impact of the expected variance of the spot prices on the magnitude of the futures premium. For 5 and 6 weeks ahead futures contracts, the futures premium has a negative and significant relationship with the expected variance of the spot prices, which is predicted by the equilibrium model. However, the expected variance has no effect on the futures premium in the monthly contracts. According to Bessembinder and Lemmon (2002), high variance of spot prices is an indication of revenue risk for the retailers, thus creates a net demand to sell futures contracts. Previous studies on the Nordic electricity market by Botterud et al. (2010) and Weron and Zator (2014) could not confirm the predictions of the equilibrium model. Our findings show that market participants can predict the expected variance in spot prices for 5 and 6 weeks ahead and incorporate it into the futures contracts. However, their ability to predict declines with longer time horizon. Hence, the pricing of 2 to 6 months ahead futures contracts does not correspond to the variations in spot prices variance.

The skewness of the spot prices was not found an important determinant of the futures premium, with an exception of 2 months ahead futures contracts that had an opposite than expected relationship. This rejects the prediction of the Bessembinder and Lemmon (2002) that there should be a positive relationship between expected skewness of spot prices and the futures premium. High skewness indicates that there is a high likelihood of upward price spikes. Therefore, the demand and prices for futures contracts should rise. One can argue that the Nordic electricity market is unique due to the presence of water reservoirs. This feature is expected to reduce the probability and magnitude of price spikes in the market. However, looking at the historical prices, spikes are still present and the skewness is positive on average. Therefore, the positive relationship with the futures premium is expected to exist even with the presence of water reservoirs. Insignificance of the skewness in the pricing of the Nordic futures contracts is confirmed by Botterud et al. (2010) and Weron and Zator (2014) in their studies.

Our findings reveal that the futures premium does not vary seasonally or monthly and its magnitude is substantially larger compared to other commodity markets. This premium is not changing in accordance to the conventional measures of risk – variance and skewness of the spot prices in the delivery period. We propose that this is due to the lack of adequate information for market participants to make reasonable predictions of these factors, assuming that market participants are rational and risk-averse. Even though the reservoir level has a predicted positive relationship on the futures premium, the variation in the premium is too high to be explained by the effect of only this risk factor. These arguments lead us to believe that there are market inefficiencies in the pricing of the futures contracts for time to maturities longer than four weeks.

7. Conclusion

The aim of this paper is to study pricing of futures contracts relative to expected future spot prices in the Nordic electricity market. Using data set of 1–6 weeks ahead weekly and 1–6 months ahead monthly futures, existence of the futures premium is confirmed and its relationship with relevant measures of risk faced by market participants is established.

First, regression with Newey-West standard errors is employed to identify whether the futures premium is present in each of the contract type chosen for the analysis. Results show that prices of the contracts with time to maturity up to 1 month are not significantly different from the expected future spot prices. However, when time to maturity increases, the futures premium becomes significant. 5–6 weeks and 2–6 months ahead contracts exhibit time-varying difference from the expected future spot prices.

These particular contracts are then examined to test properties of the premium. Confirming the findings from Gjølberg and Johnsen (2001), Botterud et al. (2002) and Botterud et al. (2009), the futures prices are on average overshooting the expected spot prices in the Nordic market. While several studies claim that the futures premium is seasonal, we find that it doesn’t change significantly through seasons, which provides support for Gjølberg and Brattested (2011).

Finally, a link between the futures prices and measures of economic risk is tested to find out whether the futures premium exist as a compensation for the risk or it is a bias present due to market inefficiencies. Equilibrium model by Bessembinder and Lemmon (2002) is augmented by adding a measure of reservoir level to account for a unique ability to store electricity in the Nordic electricity market. As predicted by the theory of storage, the reservoir level is found to have a positive relationship with the futures premium. Two factors of the equilibrium model, variance and skewness of the spot prices, are mostly insignificant. In addition, annualized futures premium is found to be 22–56% which is too high to be explained by the effect of only one risk measure. Therefore, it is concluded that there is a bias in pricing of the futures contracts with maturities longer than 4 weeks in the Nord Pool market.

For further research, it is interesting to investigate potential reasons that can explain the overpricing of the futures contracts in the market. After all it is reasonable to question why rational traders in the market have not yet exploited the opportunity by shorting the futures contracts. Gjølberg and Brattested (2011) suggest that presence of asymmetric information might cause an aggregated long-hedge demand that can generate an excessively positive futures premium. Botterud et al. (2010) believes that different risk preferences between supply and demand sides can contribute to the explanation of the observed futures premium. They argue that presence of water reservoirs gives the supply side the ability to take advantage of short-term price fluctuations. Another area of potential research could be development of derivative financial instruments to increase the amount of market participants and in turn reduce the magnitude of the futures premium. As Bessembinder and Lemmon (2002) point out, presence of futures premium at this magnitude should provide incentives for financial intermediaries to create financial instruments that attract more outside speculators. More speculative activities are then expected to increase liquidity and decrease the magnitude of the premium.

References

Bessembinder, H., & Lemmon, M. L. (2002). Equilibrium Pricing and Optimal Hedging in electricity Forward Markets. *The Journal of Finance, 57*(3), 1347-1382. doi:10.1111/1540-6261.00463

Bierbrauer, M., Menn, C., Rachev, S. T., & Truck, S. (2007). Spot and derivative pricing in the EEX power market. *Journal of Banking & Finance, 31*(11), 3462–3485. doi:10.1016/j.jbankfin.2007.04.011

Bloomberg. (2016). Data retrieved January 23, 2016, from Bloomberg database.

Botterud, A., Bhattacharyya, A. K., & Ilic, M. (2002). Futures and spot prices – an analysis of the Scandinavian electricity market. Tempa AZ: 34th Annual North American power Symposium.

Botterud, A., Kristiansen, T., & Ilic, M. D. (2010). The relationship between spot and futures prices in the Nord Pool electricity market. *Energy Economics, 32*(5), 967-978. doi:10.1016/j.eneco.2009.11.009

Bye, T., & Hope, E. (2005). *Deregulation of electricity markets - The Norwegian experience.* Statistics Norway.

Douglas, & Popova. (2008). Storage and the electricity forward premium. *Energy Economics, 4*(30), 1712-1727. doi:10.1016/j.eneco.2007.12.013

Escribano, A., Peña, J. I., & Villaplana, P. (2011). Modelling Electricity Prices: International Evidence. *Oxford Bulletin of Economics and Statistics, 73*(5), 622-650. doi:10.1111/j.1468-0084.2011.00632.x

Fama, E. F., & French, K. R. (1987). Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage. *The Journal of Business, 60*(1), 55-73.

Frankel, J. A. (1976). A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence. *The Scandinavian Journal of Economics, 78*(2), 200-224. doi:10.2307/3439924

Gjølberg, O., & Brattested, T.-L. (2011). The biased short-term future s price at Nord Pool: can it really be a risk premium? *The Journal of Energy Markets, 4*(1), 3-19.

Gjølberg, O., & Johnsen, T. (2001). *Electricity Futures: Inventories and Price Relationships at Nord Pool.* Norwegian School of Economics and Business Administration.

Gjølberg, O., & Smith-Meyer, E. (2016). *The Nordic Futures Market for Power: Finally Mature and Efficient?* NMBU School of Economics and Business.

Gorton, G., & Rouwenhorst, K. G. (2006). Facts and fantasies about commodity futures. *Financial Analysts Journal, 62*(2), 47-68. doi:10.2469/faj.v62.n2.4083

Hull, J. C. (2009). *Options, Futures and other Derivatives, 7th edition.* Upper Saddle River, New Jersey: Prentice-Hall Inc.

Kaminski, V. (1997). The Challenge of Pricing and Risk Managing Electricity Derivatives in The US Power Market. *Risk Publications*, 149-171.

Liew, V. K.-S. (2004). Which Lag Length Selection Criteria Should We Employ? *Economics Bulletin, 3*(33), 1-9.

Longstaff, F. A., & Wang, A. W. (2004). Electricity Forward Prices: A High-Frequency Empirical Analysis. *The Journal of Finance, 59*(4), 1877–1900. doi:10.1111/j.1540-6261.2004.00682.x

Lucia, J., & Schwartz, E. (2002). Electricity Prices and Power Derivatives: Evidence from the Nordic Power Exchange. *Review of Derivatives research, 5*(1), 5-50. doi:10.1023/A:1013846631785

Maynard, A. (2003). Testing for forward-rate unbiasedness: on regression in levels and in returns. *The Review of Economics and Statistics, 85*(2), 313-327. doi:10.1162/003465303765299846

McDonald, R. L. (2012). *Derivatives Markets, 3rd edition.* Pearson.

Modjtahedi, B., & Movassagh, N. (2005). Natural-gas futures: Bias, predictive performance, and the theory of storage. *Energy Economics, 27*, 617-637. doi:10.1016/j.eneco.2005.04.005

Nasdaq. (2010). *NASDAQ OMX ACQUIRES NORD POOL ASA*. Retrieved 10 April, 2016, from http://ir.nasdaq.com/releasedetail.cfm?releaseid=452675

Newey, W. K. (1985). Generalized Method of Moments Specification Testing. *Journal of Econometrics, 29*, 256-299. doi:10.1016/0304-4076(85)90154-X

Nord Pool. (2016a). *About Us*. Retrieved April 12, 2016, from http://www.nordpoolspot.com/About-us/

Nord Pool. (2016b). *Bidding areas*. Retrieved April 12, 2016, from http://www.nordpoolspot.com/How-does-it-work/Bidding-areas/

Nord Pool. (2016c). *Day-ahead market*. Retrieved April 12, 2016, from http://www.nordpoolspot.com/How-does-it-work/Day-ahead-market-Elspot-/

Nord Pool. (2016d). *Financial market*. Retrieved March 22, 2016, from http://www.nordpoolspot.com/How-does-it-work/Financial-market/

Nord Pool. (2016e). *History*. Retrieved April 12, 2016, from http://www.nordpoolspot.com/About-us/History/

Nord Pool Spot. (2015). *Annual Report 2014.* Retrieved May 24, 2016, from http://www.nordpoolspot.com/globalassets/download-center/annual-report/annual-report_nord-pool-spot-2014.pdf

Nord Pool Spot. (2016). Data retrieved January 28, 2016, from Nord Pool Spot database.

Nordic Energy Regulators. (2014). *Nordic Market Report.* Retrieved March 14, 2016, from http://www.nordicenergyregulators.org/wp-content/uploads/2014/06/Nordic-Market-Report-2014.pdf

Rademaekers, K., Slingenberg, A., & Morsy, S. (2008). *Review and analysis of EU wholesale energy markets.* Rotterdam: ECORYS Nederland BV.

Redl, C., Haas, R., Huber, C., & Böhm, B. (2009). Price formation in electricity forward markets and the relevance of systematic. *Energy Economics, 31*(3), 356–364. doi:10.1016/j.eneco.2008.12.001

Routledge, B. R., Spat, C. S., & Seppi, D. J. (1998). *The "Spark Spread:" An Equilibrium Model of Cross-Commodity Price Relationships in Electricity.* Pittsburgh, PA: Carnegie Mellon University.

Rubino, A., Costa Campi, M. T., Lenzi, V., & Ozturk, I. (2016). *Regulation and Investments in Energy Markets: Solutions for the Mediterranean* (1st ed.). Academic Press.

Stata. (2013). *corrgram — Tabulate and graph autocorrelations.* Retrieved April 10, 2016, from http://www.stata.com/manuals13/tscorrgram.pdf

Torro, H., & Lucia, J. J. (2008). *Short-term electricity futures prices: Evidence of time-varying risk premium.* Department of Financial Economics University of Valencia. doi:10.2139/ssrn.1014035

Weron, R. (2009). Heavy-tails and regime-switching in electricity prices. *Mathematical Methods of Operations Research, Springer, 69*(3), 457-473. doi:10.1007/s00186-008-0247-4

Weron, R., & Zator, M. (2014). Revisiting the relationship between spot and futures prices in Nord Pool Electricity market. *Energy Economics, 44*, 178-190. doi:10.1016/j.eneco.2014.03.007

Wooldridge, J. M. (2013). *Introductory Econometrics: A Modern Approach* (5th ed.). Mason, OH: South-Western Cengage Learning.

Appendices

Table 8. Regression results for taking away monthly, trend and break effects from the weekly variables

Dependent Variable	Obs.	Constant	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Trend	Break	Break*Trend	R^2
Spot(W)	369	-12.8071	0.0115	-0.1144**	-0.1685***	-0.2428***	-0.3370***	-0.5042***	-0.3781***	-0.3407***	-0.2553***	-0.1544***	-0.1269***	0.0065***	-0.2002***	-0.0096***	0.5636
		(1.1828)	(-0.1144)	(0.0535)	(0.0456)	(0.0462)	(0.0536)	(0.0898)	(0.0744)	(0.0671)	(0.0683)	(0.0431)	(0.0583)	(0.0005)	(0.0534)	(0.0005)	
F(W+1)	369	-12.3655***	-0.0247	-0.1363**	-0.2128***	-0.2889***	-0.3926***	-0.4760***	-0.4423***	-0.3278***	-0.2660***	-0.1756***	-0.1600***	0.0063***	-0.1650***	-0.0096***	0.6036
		(1.1049)	(0.0433)	(0.0541)	(0.0468)	(0.0444)	(0.0576)	(0.0719)	(0.0794)	(0.0600)	(0.0575)	(0.0417)	(0.0583)	(0.0004)	(0.0475)	(0.0005)	
F(W+2)	368	-10.9977***	0.0233	-0.0722***	-0.1590***	-0.2600***	-0.3291***	-0.4118***	-0.3972***	-0.2482***	-0.1943***	-0.1112***	-0.0850**	0.0057***	-0.1044***	-0.0092**	0.6481
		(1.0682)	(0.0404)	(0.0543)	(0.0511)	(0.0473)	(0.0598)	(0.0624)	(0.0767)	(0.0551)	(0.0535)	(0.0421)	(0.0511)	(0.0004)	(0.0420)	(0.0005)	
F(W+3)	367	-9.8351***	0.0279	-0.0481***	-0.1378***	-0.2390***	-0.2761***	-0.3891***	-0.3589***	-0.1960***	-0.1775***	-0.0820*	-0.0637	0.0053	-0.0441***	-0.0088***	0.6824
		(1.0326)	(0.0508)	(0.0515)	(0.0486)	(0.0559)	(0.0565)	(0.0696)	(0.0479)	(0.0539)	(0.0419)	(0.0466)	(0.0397)	(0.0004)	(0.0380)	(0.0004)	
F(W+4)	366	-9.5739***	0.0290	-0.0293	-0.1269**	-0.2109***	-0.2393***	-0.3824***	-0.3117***	-0.1932***	-0.1549***	-0.0729*	-0.0547	0.0052	-0.0222***	-0.0086***	0.6958
		(1.0586)	(0.0405)	(0.0472)	(0.0493)	(0.0469)	(0.0500)	(0.0558)	(0.0611)	(0.0462)	(0.0495)	(0.0420)	(0.0428)	(0.0004)	(0.0367)	(0.0004)	
F(W+5)	365	-9.4931***	0.0209	-0.0322	-0.1249**	-0.2117***	-0.2284***	-0.3685***	-0.2992***	-0.2086***	-0.1448***	-0.0791*	-0.0631	0.0051	-0.0063***	-0.0086***	0.7049
		(1.0782)	(0.0421)	(0.0413)	(0.0491)	(0.0456)	(0.0469)	(0.0542)	(0.0544)	(0.0456)	(0.0456)	(0.0420)	(0.0398)	(0.0004)	(0.0357)	(0.0004)	
F(W+6)	364	-9.9764***	0.0380	0.0004	-0.1064***	-0.2098***	-0.2123***	-0.3579***	-0.2890***	-0.2194***	-0.1369***	-0.0790*	-0.0580	0.0053	-0.0139***	-0.0087***	0.7127
		(1.1032)	(0.0455)	(0.0405)	(0.0475)	(0.0461)	(0.0458)	(0.0556)	(0.0501)	(0.0464)	(0.0422)	(0.0437)	(0.0381)	(0.0004)	(0.0362)	(0.0005)	
Var(W)	369	2.1469***	-0.3759	-1.0412***	-0.6242	-0.0314	0.2170	-0.8733**	-1.2696***	-0.7379*	-1.2350***	-1.1127***	0.0073				0.1200
		(0.3112)	(0.4883)	(0.3789)	(0.3990)	(0.3830)	(0.3542)	(0.3813)	(0.3853)	(0.3996)	(0.4028)	(0.3855)	(0.4173)				
Skew(W)	369	0.2623*	-0.2065	-0.1616	-0.6935***	-0.8945***	-0.9496***	-1.0497***	-0.9080***	-0.7700**	-0.5054**	-0.4447**	-0.1305				0.1608
		(0.1453)	(0.2058)	(0.2051)	(0.2107)	(0.1930)	(0.1810)	(0.2089)	(0.2147)	(0.2035)	(0.2152)	(0.2147)	(0.2289)				
Res(W)	369	59.1529***	-14.4637***	-25.0063***	-30.9723***	-21.3788***	-1.1150	12.5721***	19.3837***	21.2371***	21.7127***	18.8953***	11.0127***				0.8393
		(1.7773)	(2.4629)	(2.4968)	(2.1748)	(2.3216)	(2.2475)	(2.1468)	(2.1049)	(2.2398)	(2.2054)	(2.2676)	(2.5712)				

Notes: Standard errors are presented in parenthesis. Dependent variables: Spot(W) refers to log of average spot price during delivery week; F(W+1) is log of price of one week ahead futures contract; Skew(W) and Var(W) are skewness and variance of the spot prices during delivery month; Res (W) is average reservoir level during the delivery month. The rest of the variables are defined accordingly. Independent variables: monthly dummy variables, trend, break dummy, interaction term between break and trend variables. *Coefficient is different from 0 at 10% significance level; ** - at 5 %; and *** - at 1%.

Table 9. Regression results for taking away seasonal, trend and break effects from the monthly variables

Dependent Variable	Obs.	Constant	Spring	Summer	Autumn	Trend	Break	Break*Trend	R^2
Spot(M)	147	0.2218	-0.1091**	-0.2073***	-0.0319	0.0061***	-0.0242	-0.0194***	0.4035
		(0.5017)	(0.0542)	(0.0689)	(0.0541)	(0.0009)	(0.0918)	(0.0023)	
F(M+1)	147	0.7854	-0.1498***	-0.2303***	-0.0340	0.0052***	0.1037	-0.0203***	0.4549
		(0.4942)	(0.0517)	(0.0566)	(0.0521)	(0.0009)	(0.0857)	(0.0021)	
F(M+2)	146	1.2823***	-0.1950***	-0.2456***	-0.0821	0.0044***	0.1615**	-0.0195***	0.4887
		(0.4867)	(0.0477)	(0.0462)	(0.0530)	(0.0009)	(0.0736)	(0.0017)	
F(M+3)	145	1.3589***	-0.2127***	-0.2724***	-0.0895*	0.0043***	0.1640**	-0.0185***	0.5145
		(0.4648)	(0.0466)	(0.0482)	(0.0506)	(0.0008)	(0.0692)	(0.0016)	
F(M+4)	144	1.1172**	-0.2215***	-0.3185***	-0.1194**	0.0048***	0.1413**	-0.0179***	0.5095
		(0.5252)	(0.0518)	(0.0512)	(0.0501)	(0.0009)	(0.0680)	(0.0016)	
F(M+5)	143	1.1030**	-0.1785***	-0.3302***	-0.1285**	0.0048***	0.1205*	-0.0170***	0.5192
		(0.5368)	(0.0499)	(0.0513)	(0.0492)	(0.0010)	(0.0633)	(0.0014)	
F(M+6)	142	-0.0677	-0.1365**	-0.2872***	-0.1202**	0.0067***	0.0521	-0.0179***	0.4926
		(0.6801)	(0.0599)	(0.0545)	(0.0542)	(0.0012)	(0.0658)	(0.0015)	
Var(M)	147	2.7253***	-0.4629	-0.2601	-0.4835*				0.0274
		(0.2183)	(0.2900)	(0.2806)	(0.2896)				
Skew(M)	147	0.7724	-1.0695***	-1.3352***	-0.9363***				0.2976
		(0.1636)	(0.2064)	(0.1914)	(0.2019)				
Res(M)	147	59.3324***	-24.6880***	10.0009***	19.6465***				0.7273
		(2.0999)	(2.4678)	(2.7808)	(2.5272)				

Notes: Standard errors are presented in parenthesis. Dependent variables: Spot(M) refers to log of average spot price during delivery month; F(M+1) is log of price of one month ahead futures contract; Skew(M) and Var (M) are skewness and variance of the spot prices during delivery month; Res (M) is average reservoir level during the delivery month. The rest of the variables are defined accordingly. Independent variables: seasonal dummy variables, trend, break dummy, interaction term between break and trend variables. *Coefficient is different from 0 at 10% significance level; ** - at 5 %; and *** - at 1%.