Forward premium in Nordpool power market

Erik Haugom[1], Guttorm A. Hoff[2], Maria Mortensen[2], Peter Molnár[3], and Sjur Westgaard[2]

[1]Inland Norway University of Applied Sciences, Norway
[2]Norwegian University of Science and Technology, Trondheim, Norway
[3]University of Stavanger, UiS Business School, Stavanger, Norway

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Abstract

This paper investigates the relationship between the price of weekly futures contracts and subsequent spot prices in the Nordic power market for the time period from January 2004 to December 2013. The futures contracts have holding periods between one and four weeks. We find that futures prices are biased predictors of the subsequent spot prices and that there is a significant forward premium in the Nordpool market, particularly during the winter and autumn. We analyze several factors that are expected to have an impact on the forward premium. The average spot price and deviation of water inflow from its usual level have significant positive impacts on the forward premium. A positive impact is found also for the variable measuring the variance of the spot price, but only for the contract closest to delivery.

Keywords: electricity prices, Nord Pool, forward premium, spot price, futures price

1. Introduction

The Nordic power market is one of the most liberalized and competitive power markets in the world. It has experienced several deregulations since it was liberalized in 1991. The financial market supplements a highly volatile physical market by possibilities for risk management, hedging and speculation. Power producers want to hedge their physical delivery, while retailers want to hedge their sales obligations. The market also includes speculators willing to unload risk from producers and retailers, and bet against movement in the spot price. Futures and forward contracts are the main derivatives in the financial market. Understanding the relationship between spot and futures prices is crucial for the participants in the market. Haugom et al. (2014) finds that there is a forward premium in the Nordic market. We analyze weekly futures with holding periods between one and four weeks. Our data set consists of 10 years of data, spanning from January 1, 2004 to December 31, 2013, representing 522 weekly observations. The main reason for this choice of data is to avoid the Nordic supply shock period during winter 2002/2003, which led to an unusual rise in spot price and forward premium level (Lucia and Torró, 2011).

The goal of this paper is to explain variation in the forward premium in the Nordic electricity market using fundamental factors. We approximate the forward premium using the difference between the futures price in the trading week and the realised spot price at the time of delivery. This allows us to compare our results with previous studies, e.g., Botterud et al. (2010), Gjolberg and Brattested (2011), Lucia and Torró (2011) and Weron and Zator (2014). However, to be able to describe the premium from an ex-ante perspective, we make a slightly different assumption than in previous studies. We use only information available at the time of trading, and assume the current market conditions to influence hedging demand and expectations of future spot prices. All market participants compute the expected spot price using different models, and the assumption that all participants have the same forecasts is strict, and may lead to biased estimates. Thus, approximating forecasts using realised values as Botterud et al. (2010) precludes an ex-ante interpretation of the forward premium.

Our thesis will contribute to the literature on the relationship between spot- and futures prices in electricity markets. The analysis of Haugom and Ullrich (2012) on US day-ahead prices is interesting, but the results cannot be directly transferred to other markets or contract standards. Several papers investigate the forward premium using the realised premium as an approximation, e.g., Weron and Zator (2014) and Botterud et al. (2010). We extend the study performed by Weron and Zator (2014) by using a more recent data sample (2004-2013) and by including new explanatory variables for the Nordic market. We find that a significant forward premium exists in the Nordpool power market and that this premium is largest during winter and autumn. The variables that can explain the forward premium is the deviation of the water inflow from the average level, mean reservoir levels, and the level of the spot price.

The remainder of this paper is outlined as follows: Section 2 is a review of previous studies on relevant and related topics. Section 3 describes the data. Section 4 documents the existence of the forward premium in the Nordpool market. Section 5 presents the regression model used to analyze the variation in the ex-post risk premium. Section 6 reports the results. Finally, section 7 concludes with a summary of the main results and findings.

2. Literature review

Due to rapid developement of electricity markets, much of earlier research become outdated due to both changes in standards of financial contracts and changes in the cost structure of power producers (Botterud et al., 2010).

Botterud et al. (2002) were among the first to provide empirical evidence of a forward premium in the Nordic market. Their data set consists of observations between 1996 and 2001. They find significant and positive forward premiums, and also reveal that the magnitude increases with the length of the holding period. This is later confirmed by e.g. Gjolberg and Johnsen (2001), Mork (2006), Weron (2008) and Redl et al. (2009). Redl et al. (2009) conclude that this may be caused by supply and demand shocks in the period between trading and delivery, while not ruling out market inefficiency. Botterud et al. (2002) find a relationship between the reservoir levels and the risk premium. Botterud et al. (2010) inspect this relationship further and find that the observed risk premium can be explained by reservoir levels, average spot price in the trading week, and deviations in inflow and consumption from a long-term average in the period between trading and delivery. Botterud et al. (2010) argue that even though electricity is not storable, the theory of storage applies to this particular electricity market dominated by hydropower, because water can be stored in reservoirs. They find evidence that both storage cost and forward premium increase with the reservoir level, as there is a higher probability of water overflow in the future. Stan (2012) reaches similar conclusion. Weron and Zator (2014) study a longer price series and find limited support for the theory of storage in their data.

Stan (2012) finds a cointegrated relationship between futures and spot prices in the long run, making futures prices able to forecast spot prices. Huisman and Kilic (2012) conclude similarly. They find that futures prices in an electricity market dominated by hydro power, or other fuels which are not perfectly storable, incorporates information about expected changes in the spot price and are able to forecast spot prices.

Bessembinder and Lemmon (2002) study the PJM and CALPX[1] market, using data sets for the periods 1997–2000 and 1998–2000, respectively. They develop an equilibrium model for electricity forward prices based on the assumptions of risk averse demand and supply sides, and that electricity cannot be stored. They argue that the forward premium is a function of the variance and skewness of the spot price, having a negative and positive influence on the premium, respectively. Bessembinder and Lemmon (2002) focus on the risk averse behaviour of the market participants when explaining the size of the risk premium. They find that the premium correspond to the net hedging cost in the market. Botterud et al. (2010) argue that this model cannot be transferred to a hydro-dominated market, because of its simplifying assumptions.

Longstaff and Wang (2004) analyze the forward premium in the PJM electricity market in the period 2000-2002, using hourly spot and day-ahead forward prices. They find significant positive forward premium in their analyses. The premium is found to

[1]California Power Exchange.

be related to the volatility of unexpected changes in three risk factors: consumption, spot prices and total revenues for the system. Their analysis provides support for the model presented by Bessembinder and Lemmon. Haugom and Ullrich (2012) repeat the study of Longstaff and Wang (2004) for a longer data set in the PJM market, analyzing day-ahead futures between 2000 and 2010. They find that the premium is still positive and significant, even though it has decreased in the more recent period.

Lucia and Schwartz (2002) find evidence of a predictable pattern in Nordic spot prices in the period 1993-1999. Weron and Misiorek (2008) use air temperature as an exogenous variable to describe the spot price and find that seasonal fluctuations in water levels have impact on the influence of the temperature variable. Low reservoir levels make the temperature variable less important, and a system load variable is most likely a stronger driver in these situations.

Lucia and Torró (2011) repeat the study of Botterud et al. (2010), looking at weekly futures with time to delivery between one and four weeks in the period from 1998 to 2007. They confirm the risk premium to be positive on average, but find variation throughout the year; being zero in the summer and spring, and positive in the autumn and winter. However, they find sound evidence that circumstances changed after the shock; the spot price and risk premium increased and the seasonal pattern faded away. Mork (2006), on the other hand, find no evidence for changes in the risk premium level for block and monthly contracts in the year following the supply shock[2].

Gjolberg and Brattested (2011) call the difference between the futures and spot prices a forecast error. They argue that if this forecast error is a risk premium, it should follow a seasonal pattern based on risk expectations. Analyzing variations in the forecast error by season over the period from 1995 to 2008, they find that seasonal pattern explains too little. Still, they find the error to be greatest in the winter months (December, January and February) and mid-summer (June and July). They point out that the premium may be explained simply as a peso problem[3], although this is not likely.

Veka (2013) extend the work of Gjolberg and Brattested (2011) using a sample of daily observations between 2006 and 2012 and find that the premium shows no clear seasonal pattern, confirming the results of Gjolberg and Brattested (2011) and Botterud et al. (2010). Veka (2013) also investigates whether the forward premium is caused by the risk. He finds that the premium may include some element of risk, represented by

[2]Block contracts were offered until the start of 2003. One block amounts to four weeks. These were later replaced by monthly contracts. A small data sample in the period after the supply shock results in non-significant risk premiums. More data is needed to make further conclusions. It is possible that the supply shock made a larger impact on the long-term contracts.

[3]Market participants strongly believe that the spot price will rise dramatically as a reaction to cold weather or a dry year, and hedge against the expected high prices. Even if this event finally occurs after some time, the market has been ”wrong” for a long period. However, it is not irrational to hedge against an unfavourable event, even if this event is rather unlikely.

dependence with the implied volatility of contracts derived from the options market[4], and some element of systematic risk, represented by the dependence with returns in the equity market[5]. Still, he concludes that it is hard to explain the magnitude of the premium from these findings.

Cartea and Villaplana (2008) model the Nord Pool electricity spot price in the period 2003-2006, using variables for generation capacity, approximated by hydro reservoir level, and consumption. They find that high volatility of electricity consumption results in a higher forward premium.

Weron and Zator (2014) apply linear regression to model the ex-post risk premium for weekly futures contracts traded on Nord Pool in the period 1998-2010. They include variables observable in the trading week only: deviation in reservoir level, long-term median reservoir level and deviation in consumption and inflow[6]. To assess the validity of the Bessembinder and Lemmon (2002) model, variance and skewness of the spot price are included. Weron and Zator (2014) cannot conclude whether the forward premium is caused by the risk, or if is partly due to market inefficiencies. However, the forward premium can to a certain degree be explained by fundamental risk factors.

Gjolberg and Johnsen (2001), Redl and Bunn (2013) and Gjolberg and Brattested (2011) argue that the size of the risk premium may indicate market power among producers. Gjolberg and Johnsen (2001) analyze monthly futures and spot prices between 1995 and 2001, and argue that the Nordic market is not informationally efficient. They find futures prices and the basis to be biased and poor predictors of future spot prices, and show that including publicly available information improves the forecasts of the spot price. As an explanation Gjolberg and Johnsen (2001) suggest an abuse of market power from the producers' side, but without an evidence to support this. However, Hjalmarsson (2000) performs a study of market power in Nord Pool and he is not able to reject the null hypothesis of perfect competition. Fridolfsson and Tangerås (2009) find no evidence of market power in the Nordic power exchange either. Amundsen and Bergman (2006) reason that use of market power in a hydropower dominated market is unlikely, and convincing evidence is lacking. They claim that, among other factors, the flexibility in choice of power suppliers, and the "public service attitude"[7] in the power companies, have reduced the possibility of market power abuse.

Benth et al. (2008) investigate relationships between the risk premium and the behaviour and risk preferences of the market participants in the German electricity market. They find that in cases with high probability of price spikes and during short-term horizons, power producers have the largest market power as consumers are more eager to hedge their obligations. This results in consumers paying a high

[4]The options are at-the-money, and have quarterly contracts as underlying assets. The implied volatility is interpreted as the forward-looking risk the participants are facing at the time of trading.

[5]Three different benchmark indices are used: OMX Copenhagen 20, DAX and FTSE 100.

[6]The trading week deviations are used as forecasts of future deviations in consumption and inflow. Weron and Zator (2014) believe this makes the model valid for ex-ante estimation of the risk premium.

[7]The Nordic power industry is committed to deliver a public service, although market competition has existed for several years (Amundsen and Bergman, 2006).

premium. On the other hand, the market risk premium for contracts with delivery further into the future trades at a lower premium, and often at a discount. Hence, the producers' market power and risk premium is a decreasing function of maturity for monthly, quarterly and yearly forward contracts.

3. Data

In this section we introduce the data we use in this paper together with summary statistics for the most relevant variables. Table 1 briefly summarizes the data together with the sources where we obtained them. More detailed analyses follow later.

Table 1: *The table provides the source of the data, time period and frequency.*

Data	Source	Time period	Frequency
Spot	Montel[8]	1996-2013	Hourly
Futures	Montel	2004-2013	Hourly
Consumption	Montel	2000-2013	Hourly
Inflow	Nord Pool FTP server	1996-2013	Weekly
Wind production	Energinet.dk[9]	2000-2013	Daily
Reservoir level	Nord Pool FTP server	1996-2013	Weekly

3.1. Spot price

The daily spot or system price data is collected from the information provider Montel, cf. Table 1 in the appendix. A time series of weekly prices was generated using the arithmetic average of daily spot prices from Monday to Sunday[10]. The spot prices were also divided into the four seasons[11], which allows us to observe seasonal dynamics. Table 2 provides descriptive statistics for the weekly average spot price in the period January 1, 2004 to December 31, 2013.

The mean spot price is 308.99 NOK/MWh for the entire sample. We observe the highest average price during winter (336.71 NOK/MWh), and the lowest during summer (276.25 NOK/MWh). This is as expected in the Nordic market. Figure 1 plots the spot price and its changes in the period 2004-2013. Though the spot prices exhibit large variations over time it is hard to identify a distinct seasonal pattern by just visual inspection. There is an increase in the spot price level after 2005. Sijm et al. (2006) find that the introduction of ETS explains much of this increase in spot prices[12]. The market also experienced high spot prices in 2010. Maintenance on several Swedish nuclear power plants was performed during this year to prevent unscheduled stops in

[8] Montel (2014)

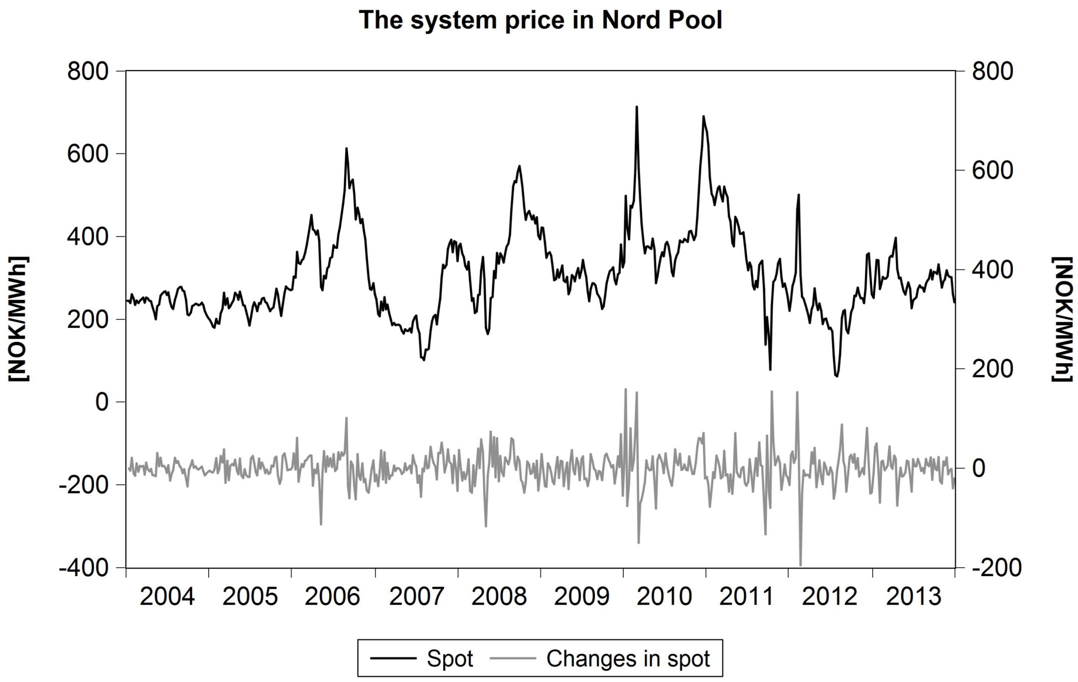
[9] Energinet.dk (2014)

[10] Starting from 2006, all contracts were quoted in Euro. We use the daily exchange rates from Norges Bank (Norges Bank, 2013) to convert the futures prices to NOK.

[11] Winter is defined as week 47 to 7. The other seasons are defined using consecutive thirteen-week periods.

[12] The introduction of ETS in 2005 changed the cost structure for the power producers with carbon emissions. In an integrated market, this will influence the water values and the scheduling of hydro resources.

Figure 1: *The figure shows the daily system price in Nord Pool for the period 2004-2013. Changes in the system price is plotted in the bottom graph. All data is given in NOK/MWh.*



production. The plants downtime contributed to high spot prices. In addition, this was a dry year with low reservoir levels[13] and with both winters 2009/2010 and 2010/2011 being unusually cold. Relatively high temperatures and substantial precipitation, accompanied by high production of wind power in Denmark, caused the spot prices to plummet to a low level in 2011. Low spot prices were also observed in 2012, due to high inflow caused by late snow melting in the mountains.

The spot price is highly volatile with a standard deviation of 103.71 NOK/MWh for the entire sample. Fall and winter have the highest volatility levels of 110.41 NOK/MWh and 109.49 NOK/MWh, respectively. The lowest volatility is experienced during summer (86.14 NOK/MWh). The extreme volatility is well documented in the literature, e.g., Lucia and Schwartz (2002), Lucia and Torró (2011), Weron and Zator (2014) and Gjolberg and Johnsen (2001). Excess kurtosis and a right skewed distribution suggest frequent spikes in the spot price. The Jarque-Bera test statistics rejects the null hypothesis of a normal distribution for the whole sample. The hypothesis cannot be rejected for the summer sample, and the fall sample is only rejected at a 10% significance level. The whole sample is tested for stationarity using the ADF unit root

[13]The deficit in reservoir levels reached a maximum value of 30 TWh (NordREG, 2011).

Table 2: *The table provides descriptive statistics for the weekly spot price. Winter is defined from week 47 to 7, and the other seasons are defined by the subsequent 13 week periods. All prices are in NOK/MWh. ***, **, and * indicate rejection of the null hypothesis stating normal distribution at a 1%, 5% and 10% level, respectively.*

	Prices				
	All	Winter	Spring	Summer	Fall
Mean	308.99	336.71	304.22	276.25	318.36
Std. error	4.54	9.53	8.63	7.55	9.68
Std. deviation	103.71	109.49	98.37	86.14	110.41
Minimum	62.14	180.34	165.11	62.14	78.29
Median	290.47	307.93	277.04	273.86	290.68
Maximum	714.08	690.52	714.08	511.93	613.37
Skewness	0.84	1.10	1.08	-0.15	0.68
Excess Kurtosis	0.97	0.92	1.39	0.03	-0.23
Jarque-Bera	81.76***	31.16***	35.82***	0.50	10.40*

test (Dickey and Fuller, 1979). The null hypothesis of non-stationarity is rejected at a 5% significance level for both the raw and the log prices.

3.2. Futures prices

We use weekly futures contracts with time to delivery of between one and four weeks[14]. The weekly futures prices are provided from Montel and summary statistics are presented in Table 3.

Weekly futures contracts have two main advantages. The sample size of these futures is sufficiently large to carry out meaningful analyses. Additionally, by using these contracts we can compare our results with those obtained in previous research within this field. Examples include Botterud et al. (2010), Lucia and Torró (2011) and Weron and Zator (2014). One possible drawback with weekly futures is the low liquidity of contracts with long maturity.

Futures prices are collected at three different points in time: (1) The closing price on the last day of trading (hereinafter called *closing price*), (2) the average closing price during the last trading week (hereinafter called *average price*) and (3) the closing price on the day with the highest trading volume during the last trading week (hereinafter called *volume price*). Descriptive statistics are provided for the different alternatives, cf. Table 3. We report summary statistics also for the logarithm of closing price. The statistics for the logarithmic average and volume prices are very similar and due to space considerations we do not report them.

[14]Hereinafter, we will refer to a futures contract with one week to delivery as F1, a futures contract with two weeks to delivery as F2, and so on.

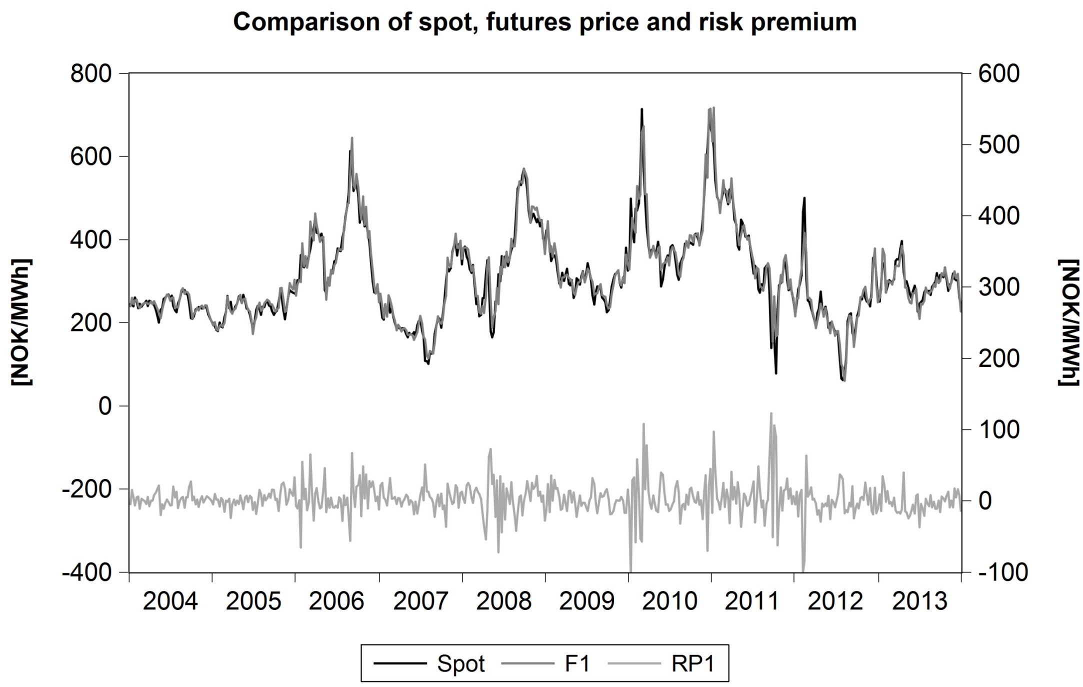
Table 3: *The table shows the descriptive statistics for the futures contracts. The mean and standard deviation are given in NOK/MWh. The columns reflect holding periods of one, two, three and four weeks. ***, **, and * indicate rejection of the null hypothesis stating normal distribution at a 1%, 5% and 10% level, respectively.*

	Closing prices			
	1	2	3	4
Mean	311.99	317.12	320.04	321.06
Std. deviation	104.93	103.56	100.77	98.76
Skewness	0.96	0.93	0.88	0.86
Excess Kurtosis	1.24	1.00	0.71	0.57
Jarque-Bera	112.95***	97.58***	79.08***	72.14***
	Average prices			
	1	2	3	4
Mean	313.37	317.75	319.50	320.76
Std. deviation	103.28	101.27	98.79	97.10
Skewness	0.95	0.91	0.85	0.83
Excess Kurtosis	1.24	0.94	0.61	0.48
Jarque-Bera	112.01***	90.30***	70.36***	64.17***
	Volume prices			
	1	2	3	4
Mean	313.09	316.74	319.52	320.73
Std. deviation	104.55	101.17	98.36	97.94
Skewness	0.97	0.91	0.83	0.86
Excess Kurtosis	1.22	1.01	0.49	0.64
Jarque-Bera	114.45***	93.43***	65.45***	73.27***
	Log closing prices			
	1	2	3	4
Mean	5.69	5.71	5.72	5.73
Std. deviation	0.33	0.32	0.31	0.30
Skewness	-0.24	-0.07	0.06	0.11
Excess Kurtosis	1.07	0.42	-0.15	-0.30
Jarque-Bera	29.71***	4.35	0.82	3.06

Figure 2 compares the spot price to the F1 closing price[15]. As can be seen from the

[15]The plots for the average and volume prices are very similar, thus not reported.

Figure 2: *The figure shows the daily Nord Pool system price and the F1 contract price in the period 2004-2013. The raw risk premium, given in Equation* (2)*, is plotted on the bottom graph. All data is given in NOK/MWh.*



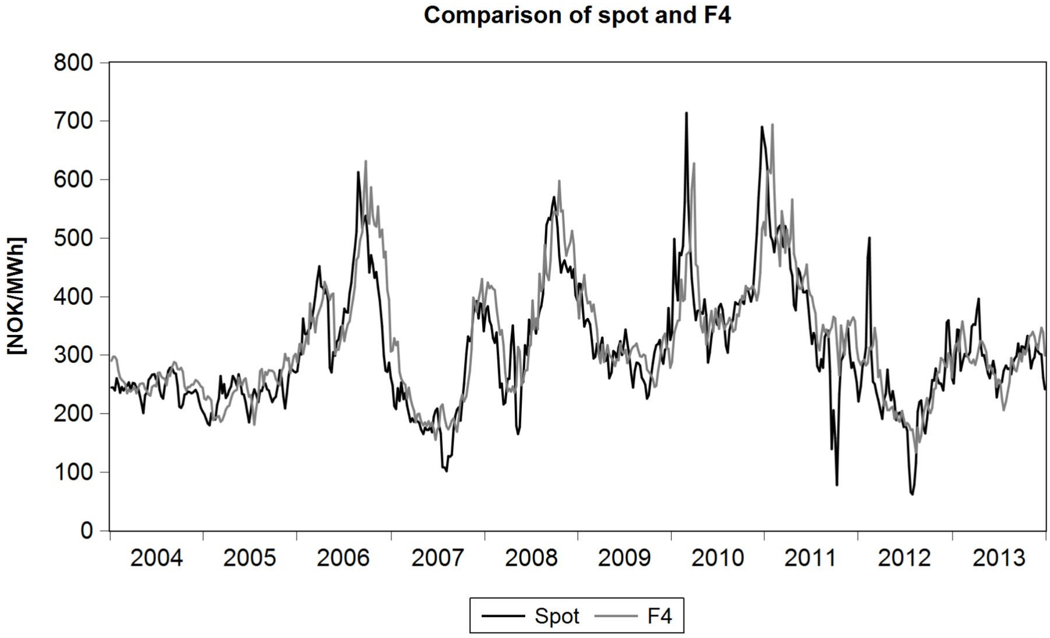
figure, the price of the forward contract follows the spot price closely throughout the entire sample. Figure 3 compares the spot price to the F4 closing price[16]. By visual inspection of Figure 2 and 3, we observe that futures contracts with longer holding periods appear to react slower to changes in the spot price, compared to futures with shorter holding periods.

The futures prices show many of the same features as the spot price. Considering the closing prices, the excess kurtosis is 1.24 for F1 and 0.57 for F4. The negative relationship between the kurtosis and the holding period is expected as contracts with longer holding periods do not reach extreme values as frequently as the spot price and the front futures contracts. This can be seen from Figure 2 and 3, and also explains the lower volatility in these contracts. The mean value of the contracts increase with the holding period.

The Jarque-Bera test statistic rejects the null hypothesis of normality at a 1% significance level. However, the natural logarithm of the closing prices are normally

[16]As for the F1 contract, the average and volume prices are very similar to the closing prices and not reported.

Figure 3: *The figure shows the daily Nord Pool system price and the F4 contract price in the period 2004-2013. All data is given in NOK/MWh.*



distributed for the contracts with two, three and four weeks to delivery. The null hypothesis of non-stationarity is rejected at a 10% significance level for futures and log futures prices using an ADF unit root test.

3.3. *Other variables*

Physical conditions are likely to have impact on spot and futures prices. The Nordic climate is characterized by cold winters and relatively warm summers. As 50% of the power produced is hydropower, the hydrologic conditions will influence the market. Also, the production of wind power has increased in the recent years and influence the power dynamics due to low marginal costs.

Figure 4 plots the temperature, inflow and consumption in the period 2004-2013. Inflow is the total inflow in Norway and Sweden. The consumption is the total consumption in Norway, Sweden, Denmark and Finland. Temperature is an approximation of the mean temperature in Norway, calculated as the average of five geographically spread Norwegian cities. We observe a clear negative dependence between temperature and consumption, and a positive dependence between temperature and inflow. Both findings are as expected; the consumption decreases due to a lower power demand for heating purposes. The inflow increases due to the snow melting in the spring and precipitation throughout the year. We notice a distinct seasonal pattern for consumption and temperature. Since both inflow and consumption exhibit seasonal pattern, we include in the analysis only inflow. An additional reason why not to include temperature in the analysis is that the impact of temperature on the electricity prices is only indirect, via electricity consumption[17], and electricity consumption is included as one of the explanatory variables.

Figure 5 reveals some evidence of low spot prices when the inflow reaches its maximum during spring and early summer, but this pattern is not consistent throughout the entire time period. Figure 6 plots the reservoir level, the deviation in reservoir level from the median and the spot price. The reservoir level is the water level given as a percentage of total capacity in Norway and Sweden, and is a direct consequence of inflow and consumption. We observe a seasonal pattern in the water level, although the top and bottom values vary over the time period. The deviation in reservoir level is calculated as the difference between the actual reservoir level and a long-term median. Water levels in the period 1995-2013 are used to construct the median. The vertices of the reservoir level and the spot price coincide in the period 2006-2008, but in the subsequent period the spot prices seem to be somewhat "delayed". This may be related to the increasingly negative deviation in reservoir level, caused by the cold winters in 2009/2010 and 2010/2011. High spot prices are observed when the deviation is the most below the normal level, e.g., late 2006 and during winter 2010/2011. Besides from this, there is no evident pattern related to the deviation in reservoir level. Figure 7 plots the spot price and the wind power in the period 2004-2013. The wind power is the actual wind power produced in Denmark. As can be seen from the figure, the amount of power produced is very volatile. However, there is a weak seasonal pattern representing more wind during the winter. We find it difficult to observe any distinct relationship between the wind power produced and the spot price level.

[17]The impact of the temperature on the electricity consumption is studied in e.g. Bašta and Helman (2013) and Do et al. (2016)

Figure 4: *The figure plots temperature, inflow and consumption in the period 2004-2013. The temperature is an approximation of the mean temperature in Norway. Inflow is the total inflow in Norway and Sweden. Consumption is the total consumption in Norway, Sweden, Denmark and Finland. Inflow and consumption($\times 10^{-3}$) are measured on the left axis and given in MWh. The temperature is measured on the right axis and given in $^{\circ}$C.*

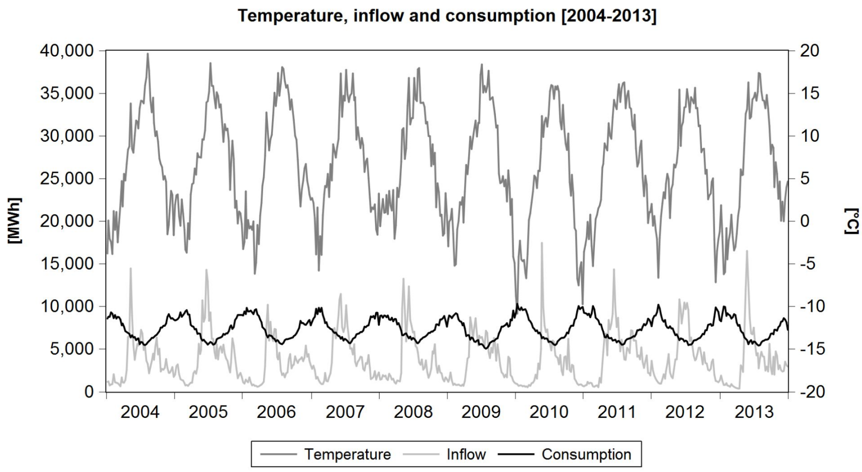


Figure 5: *The figure plots the inflow and spot price in the period 2004-2013. The inflow is the total inflow in Norway and Sweden. The spot price is measured on the right axis and given in NOK/MWh, while the inflow is measured on the left axis and given in MWh.*

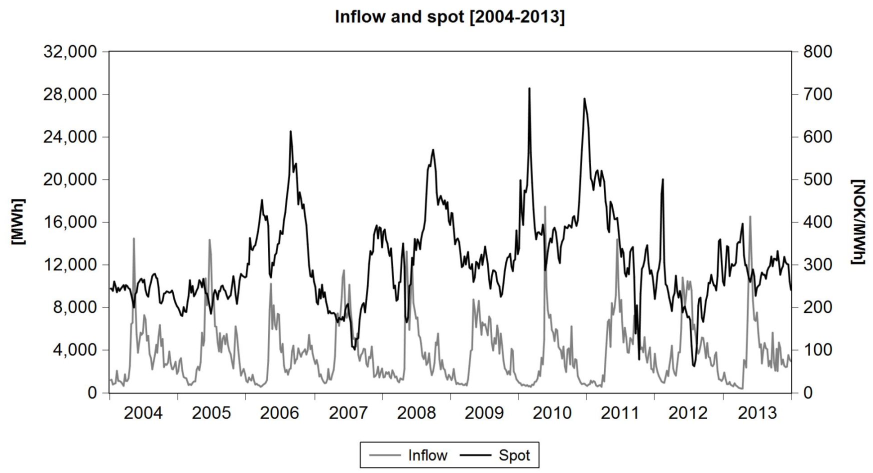


Figure 6: *The figure plots the reservoir level, the deviation in reservoir level from a long-term median and the spot price in the period 2004-2013. The reservoir level is the actual water level in Norway and Sweden, divided by the total reservoir capacity. The median reservoir level is calculated from weekly average reservoir levels in the period 1995-2013. Both the reservoir and deviation are measured on the left hand scale and given as percentages. The spot price is measured on the right axis and given in NOK/MWh, while the inflow is measured by the left axis and given in MWh.*

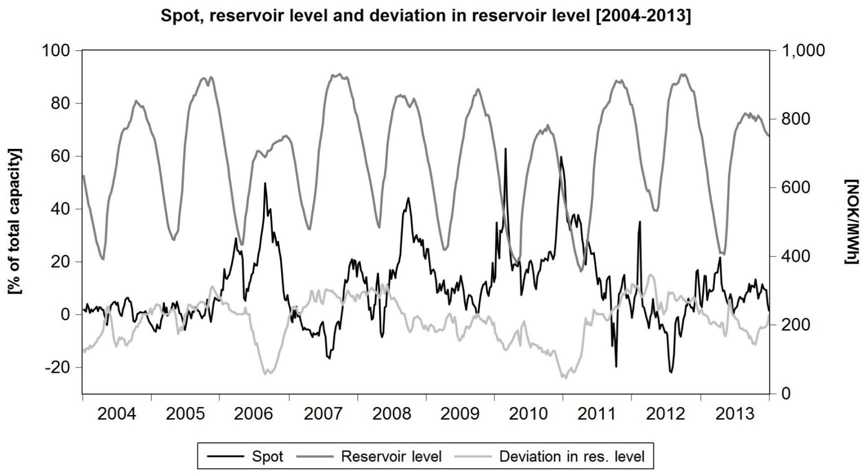
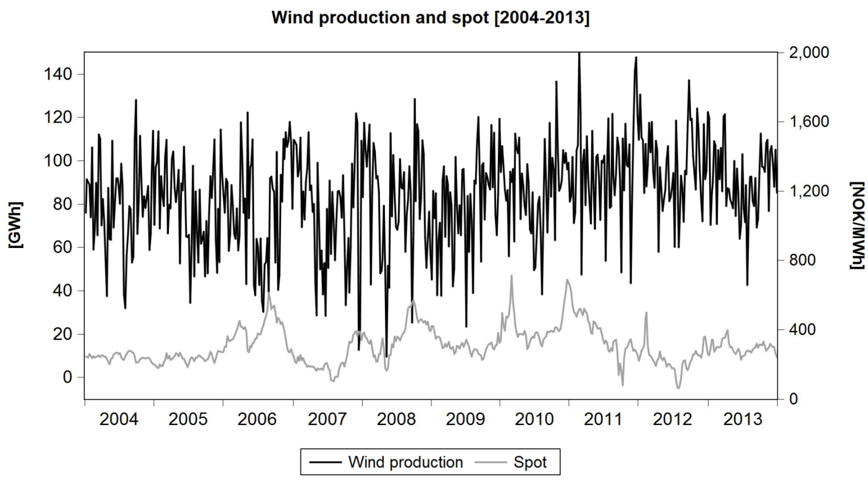


Figure 7: *The figure plots the actual produced wind power in Denmark, and the spot price, in the period 2004-2013. The wind power is measured on the left axis and given in GWh, while the spot price is measured on the right axis and given in NOK/MWh.*



4. Forward premium

The difference between the current futures price and the current spot price, the basis, can be expressed as the sum of expected change in the spot price and the forward premium (see Fama and French (1987)):

$$F_{t,t+T} - S_t = E_t[S_{t+T} - S_t] + FP^{ea}_{t+T}. \tag{1}$$

$F_{t,t+T}$ is the time t futures price with holding period T and delivery in $t+T$, and S_t is the spot price at time t. In this definition, the forward premium FP^{ea}_{t+T} is the expected, ex-ante, forward premium, i.e., $FP^{ea}_{t+T} = F_{t,t+T} - E_t[S_{t+T}]$.

The ex-ante forward premium is investigated in Bessembinder and Lemmon (2002). However, the expected spot price is not directly observable. Since the results would depend on the model applied, researchers often choose to investigate the ex-post forward premium defined as (see Botterud et al. (2010), Lucia and Torró (2011), Gjolberg and Brattested (2011), Haugom and Ullrich (2012) and Weron and Zator (2014)):

$$FP^{ep}_{t+T} = F_{t,t+T} - S_{t+T}, \tag{2}$$

where S_{t+T} is the average spot price in the delivery week $t+T$ and $F_{t,t+T}$ is the futures price. We follow this practice and study the ex-post forward premium.

A choice has to be made on which futures price to use in the calculations. We consider three definitions of the futures price in this paper: the closing futures price on the last trading day of the final trading week, t, the average closing futures price during week t and the closing futures price on the day with highest traded volume during week t.

The relation between the ex-post and ex-ante forward premium is as follows:

$$FP^{ep}_{t+T} = FP^{ea}_{t+T} + E_t[S_{t+T}] - S_{t+T}. \tag{3}$$

In other words, the ex-post forward premium is equal to the sum of the ex-ante forward premium and the difference between the expected future spot price and the realized spot prize in the future.

For the sake of robustness, we also examine the log ex-post forward premium, LFP^{ep}_{t+T}, defined as:

$$LFP^{ep}_{t+T} = lnF_{t,t+T} - lnS_{t+T}. \tag{4}$$

Table 4 and 5 present descriptive statistics for the logarithmic and raw forward premium. The forward premiums are significantly different from zero in most cases. To arrive at this conclusion, we have run the following regressions;

$$LFP_{t+T} = \alpha \quad \text{and} \quad FP_{t+T} = \gamma. \tag{5}$$

Table 4: *The table shows the descriptive statistics for the log forward premium based on the various methods for calculating the futures price. The columns reflect holding periods of one, two, three and four weeks. ***, **, and * indicate significance at a 1%, 5% and 10% level, respectively, based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator.*

	FP calculated from closing log prices			
	1	2	3	4
Mean	0.011***	0.031***	0.044***	0.050***
Std. deviation	0.088	0.143	0.174	0.198
Skewness	2.51	2.42	1.39	1.43
Excess Kurtosis	18.96	17.68	6.32	6.89
	FP calculated from average log prices			
	1	2	3	4
Mean	0.018***	0.036***	0.044***	0.050***
Std. deviation	0.103	0.153	0.183	0.203
Skewness	3.02	2.16	1.46	1.36
Excess Kurtosis	23.23	13.94	6.90	6.76
	FP calculated from volume log prices			
	1	2	3	4
Mean	0.016***	0.032***	0.045***	0.049***
Std. deviation	0.101	0.149	0.178	0.201
Skewness	2.80	2.18	1.42	1.38
Excess Kurtosis	22.82	14.70	6.06	6.94

Hence, these regression models test the null hypothesis that the log forward premium (α) and the forward premium (γ) are equal to zero. The significance level is based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator (Newey and West, 1986).

Since longer time horizons means more uncertainty, the forward premium increases with time to delivery. This is true for all the various methods of calculating the futures price. Considering the log forward premiums for the different maturities, the closing prices for the F1 and F2 contracts provide the smallest premiums. Using the average futures prices induce the highest forward premiums for the F1 contract. This confirms the results of Redl et al. (2009) who find that using futures prices on the last trading day, instead of monthly averages in the last trading month, lowers the difference between spot and futures prices. This is reasonable, as the futures prices closest to delivery include more information, and should therefore be better at predicting the subsequent spot prices. The skewness and excess kurtosis decrease with time to maturity. The

Table 5: *The table shows the descriptive statistics for the forward premium (FP) based on the various methods for calculating the futures price. The columns reflect holding periods of one, two, three and four weeks. ***, **, and * indicate significance at a 1%, 5% and 10% level, respectively, based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator.*

	FP calculated from closing prices			
	1	2	3	4
Mean	2.998***	8.132***	11.051***	12.069***
Std. deviation	23.117	40.300	51.034	58.580
Skewness	0.37	0.48	0.18	0.01
Excess Kurtosis	5.81	5.52	3.04	2.62
	FP calculated from average prices			
	1	2	3	4
Mean	4.379***	8.755***	10.511***	11.766**
Std. deviation	27.428	43.752	53.543	60.431
Skewness	0.37	0.22	0.07	-0.16
Excess Kurtosis	6.71	5.83	2.81	2.96
	FP calculated from volume prices			
	1	2	3	4
Mean	4.102***	7.747***	10.531***	11.739**
Std. deviation	27.436	42.804	51.809	60.139
Skewness	0.14	0.28	0.06	-0.09
Excess Kurtosis	6.22	5.50	2.73	2.96

Table 6: *The table shows the descriptive statistics for the realised log forward premium by season. Closing futures prices on the last day of trading are used in the calculations. The columns reflect holding periods of one, two, three and four weeks. ***, **, and * indicate rejection of significance at a 1%, 5% and 10% level, respectively, based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator.*

	Winter			
	1	2	3	4
Mean	0.012**	0.035***	0.049**	0.059**
Std. deviation	0.067	0.113	0.152	0.185
Skewness	-1.03	-0.58	-0.27	-0.48
Excess Kurtosis	3.13	1.55	0.48	0.67
	Spring			
	1	2	3	4
Mean	0.008	0.022	0.028	0.028
Std. deviation	0.069	0.132	0.165	0.183
Skewness	1.19	0.98	0.71	0.51
Excess Kurtosis	4.35	3.54	2.11	0.65
	Summer			
	1	2	3	4
Mean	0.006	0.026	0.044*	0.052*
Std. deviation	0.092	0.149	0.183	0.202
Skewness	1.68	1.69	1.88	2.20
Excess Kurtosis	7.32	6.86	7.42	7.20
	Fall			
	1	2	3	4
Mean	0.019*	0.042**	0.056**	0.061*
Std. deviation	0.116	0.174	0.196	0.219
Skewness	3.48	4.11	2.13	2.48
Excess Kurtosis	20.28	26.70	8.75	12.16

forward premiums for the contracts with longer holding periods have more symmetric and less leptokurtic distributions.

The hypothesis that futures prices are unbiased predictors of future spot prices is called the unbiased forward rate hypothesis (UFH). According to the view of an efficient market in a weak-form, all the historical spot price information is included in the futures prices. We can test the UFH by running the following regression model:

Table 7: *Tests of unbiased forward rate hypothesis on raw prices, defined in Equation* (6)*, using OLS regression. The sample period is from January 1 2004 to December 31 2013. The columns reflect holding periods from one to four weeks. Q(10) is the Ljung-Box Q-statistic using 10 lags. ***, **, and * indicate significance at a 1% level, 5% level and 10% level, respectively, based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator. Note: The stars on Q(10) reflect significance based on the* χ^2 *test statistic. The null hypothesis states that* $\alpha = 0$ *and* $\beta = 1$*.*

	Closing prices			
	1	2	3	4
α	8.20**	15.43*	20.53	27.94*
β	0.96***	0.93***	0.90**	0.88**
R^2	0.95	0.85	0.77	0.70
	Average prices			
	1	2	3	4
α	5.38	13.17	20.13	27.79*
β	0.97**	0.93**	0.90**	0.88**
R^2	0.93	0.83	0.74	0.67
	Volume prices			
	1	2	3	4
α	9.19**	12.58	15.96	29.30*
β	0.96***	0.94**	0.92*	0.87**
R^2	0.93	0.83	0.76	0.68

$$S_{t+T} = \alpha + \beta F_{t,t+T} + \epsilon_{t+T} \tag{6}$$

where we test whether $\alpha = 0$, $\beta = 1$. Following Haugom and Ullrich (2012) we interpret an alpha significantly different from zero as evidence of a systematic forward premium, and a beta significantly different from one as evidence of futures prices being biased predictions of the subsequent spot prices.

Since spikes are present in the spot prices, we follow Haugom and Ullrich (2012) and perform UFH regression using the natural log of both the futures and spot prices. In particular, we estimate the following model:

$$lnS_{t+T} = \alpha + \beta lnF_{t,t+T} + \epsilon_{t+T}. \tag{7}$$

The results from the regression (6) using the closing-, average-, and volume futures prices are presented in Table 7 and the results for the log prices (7) are reported in Table 8.

Table 8: *Tests of unbiased forward rate hypothesis on logarithmic prices, defined in Equation (7), using OLS regression. The sample period is from January 1 2004 to December 31 2013. The columns reflect holding periods from one to four weeks. Q(10) is the Ljung-Box Q-statistic using 10 lags. *, ** and *** reflect significance based on the χ^2 test statistic. The null hypothesis states that $\alpha = 0$ and $\beta = 1$.*

	Closing log prices			
	1	2	3	4
α	0.020	0.112	0.155	0.280
β	0.994	0.975	0.965	0.942
R^2	0.934	0.827	0.742	0.672
	Average log prices			
	1	2	3	4
α	-0.049	0.046	0.173	0.293
β	1.005	0.986	0.962	0.940
R^2	0.911	0.802	0.716	0.653
	Volume log prices			
	1	2	3	4
α	-0.013	0.058	0.078	0.306
β	0.999	0.984	0.979	0.938
R^2	0.914	0.812	0.732	0.659

Table 7 present the results of the regressions using the raw spot and futures prices in Equation (6) provide different results. The results vary slightly depending on which futures prices are used, but the overall findings suggest that futures prices are biased predictors of the subsequent spot prices. Closing-, average-, and volume futures prices for all maturities provide beta estimates lower than one. The beta estimates decrease with time to maturity. If interpreting the beta estimate as a forecast error, this finding provide evidence of increased difficulties related to prediction of the spot price far from delivery. Using the closing futures prices induce significant alpha estimates for contracts of one, two and four weeks holding period. Alpha, representing the systematic forward premium, increases with time to maturity. Using the average futures prices the only significant value of alpha is found for the contract with four weeks holding period. Using the volume prices reveals significant alphas for the contracts with one and four weeks to delivery.

Estimated coefficients for Equation (7) provide no evidence of the futures prices being biased forecasts of the subsequent spot prices. For this model specification the alpha parameter is not significantly different from zero for any of the three ways of calculating the futures price.

In next sections we study how variations in the forward premium can be explained using fundamental information.

5. The model and preliminary analysis

In order to calculate the forward premium the expected future spot price is needed. However, models used to estimate the expected spot prices differ between market participants. Therefore, whenever researchers try to test the presence of a forward premium, it is essentially a joint test of the existence of forward premium and the model for expected spot price. In this paper, we therefore follow Haugom and Ullrich (2012) and study the realized forward premium.

The timing of observations is particularly important in our analysis. Previous literature use explanatory variables from the actual trading week, in the delivery week, or in the time between, when investigating the forward premium. We focus on the risk factors the market participants face at the time the futures contracts are traded. Using information known at the time of trading gives us the opportunity to assume that all market participants have the same information. This allows us to construct a model describing how fundamental factors affect the ex-post forward premium. To make the analysis comparable to Weron and Zator (2014) and Botterud et al. (2010), the model is formulated with the log forward premium as the dependent variable.

$$\begin{aligned} LFP_{t+T} = \alpha &+ \beta_1 CONSD_t + \beta_2 INFD_t + \beta_3 WINDP_t \\ &+ \beta_4 RESM_t + \beta_5 RESD_t + \beta_6 VAR_t + \beta_7 S_t + \epsilon_t \end{aligned} \tag{Model 1}$$

where LFP_{t+T} is the realised log forward premium in week $t+T$, $CONSD_t$ is the total deviation in actual electricity consumption in Norway, Sweden, Denmark and Finland from the average (2000–2013), in week t [MWh], $INFD_t$ is the deviation in actual inflow in Norway and Sweden from the average (1996–2013), in week t [MWh], $WINDP_t$ is the wind production in Denmark in week t [GWh], $RESM_t$ is the median reservoir level in Norway and Sweden (1995-2013) in week t [%], $RESD_t$ is the deviation in actual reservoir level in Norway and Sweden from the median ($RESM_t$) in week t [%], VAR_t is the variance of hourly spot prices in week t, S_t is the spot price in week t [NOK/MWh] and ϵ_t is the error term.

The explanatory variables used in Model 1 are chosen based on previous studies on the forward premium and preliminary analyses on the conditions in the Nordic market. We only include variables from the trading week, and investigate how these drive the realised forward premium.

Before the models were estimated, the stationarity is tested for using the Phillips-Perron test (Phillips and Perron, 1988) and the ADF unit root test. The null hypothesis of unit root is rejected for all time series.

We apply a method from Weron (2006) to reduce the effect from spikes in the time series. Weron (2006) finds that the *Damped* method performs the best, and Weron and Misiorek (2008) apply this method to their time series of hourly spot prices. We set an upper and lower limit for the log premium. If LFP_{t+T} is outside the interval, the premium is set to:

$$LFP^*_{t+T} = T + T \times log_{10} \frac{LFP_{t+T}}{T}. \tag{8}$$

The upper and lower limits are

$$T = \mu + N \times \sigma \qquad \text{and} \qquad T = \mu - N \times \sigma, \tag{9}$$

respectively, where μ is the mean log forward premium and σ is the standard deviation. N is the number of standard deviations, and the lower the number, the stricter the damping of the premium. Weron (2006) proposes using $N = 3$. We also calculate the limits using two standard deviations, $N = 2$. Hereinafter, the models with damped spikes will be referred to as Model 2 ($N = 2$) and Model 3 ($N = 3$).

6. Results

The results from the regressions are reported in 9 and 10, with regular and standardized coefficients, respectively. Regression results when excluding the spot price from the models are also reported in this table (panel b). The standardized coefficients are reported to assess the relative magnitude of the impact of each variable on the forward premium. These regression coefficients show how many standard deviations the dependent variable changes, given one standard deviation change in the independent variable - everything else equal.

The explained variance is low for both model specifications and for all maturities. As expected, the R^2 decreases with time to maturity as the trading week conditions contains the most information about the delivery period for the nearest contracts. Considering Model 1a, R^2 is 0.043 for the contracts with one to three weeks holding period, while it is 0.040 for the contract with four weeks holding period.

INFD is the only variable with significant coefficients for all models and contract maturities[18]. The coefficient is positive which is in line with our expectations and the results of Botterud et al. (2010) and Weron and Zator (2014). Weron and Zator (2014) find significant effects for the two contracts in front only. The RESM coefficient provides some evidence of a direct effect between the reservoir level and the forward premium. For some model specifications and maturities, this variable has a significant effect. The sign of the coeffisients is always positive meaning that higher reservoir levels induce higher forward premia. This finding is somewhat unexpected as an increase in the current supply level should induce lower futures prices and hence a lower forward premium. However, an increase in current supply will also lower future spot prices, which in turn will lead to a positive effect on the premium.

Weron and Zator (2014) and Lucia and Torró (2011) found the deviation in reservoir level to be significant. As different time series are analysed, this indicates that deviation

[18]The damped models excluding the spot price do not have a significant INFD coefficient for LFP4.

in reservoir level at the time of trading is not able to describe variation in the premium, when we control for the other variables included in the model.

The significant effects from VAR, INFD and the spot price indicate that these are risk factors driving parts of the forward premium. This provides some evidence of the the forward premium can be partly related to risk factors in the market.

Table 10 reports the results of the regression using standardized coefficients. Standardized coefficients simplify the comparison of the magnitude of the impact of various explanatory variables on the risk premium. One standard deviation increase in INFD, results in a 1.19 % increase in LFP1 and a 2.67 % increase in LFP4. Increasing the VAR variable with one standard deviation, increases LFP1 with 1.06 %, while a one standard deviation increase in the spot price increases LFP4 with 3.28 %.

Table 9: *Regression results from Model 1, Model 2 and Model 3. The sample period is from January 1 2004 to December 31 2013. ***, **, and * indicates significance at a 1%, 5% and 10% level, respectively, based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator. $CONSD_t$ is the total deviation in actual electricity consumption in Norway, Sweden, Denmark and Finland, from the average (2000–2013), in week t [MWh], $INFD_t$ is the deviation in actual inflow in Norway and Sweden from the average (1996–2013), in week t [MWh], $WINDP_t$ is the wind production in Denmark in week t [GWh], $RESM_t$ is the median reservoir level in Norway and Sweden (1995-2013) in week t [%], $RESD_t$ is the deviation in actual reservoir level in Norway and Sweden from median ($RESM_t$) in week t [%], VAR_t is the variance of hourly spot prices in week t, S_t is the spot price in week t [NOK/MWh]*

			CONSD ($\times 10^7$)	INFD ($\times 10^4$)	WINDP ($\times 10^6$)	RESM	RESD	VAR ($\times 10^5$)	S ($\times 10^3$)	C	R^2	$R^2(adj.)$
M1	a	LFP1	-1.300	0.899 **	-2.460	0.034 *	0.000	3.550 *	0.615	-0.014	0.043	0.030
		LFP2	-1.500	1.760 *	-2.830	0.066	0.031	2.230	1.800 *	-0.045	0.043	0.030
		LFP3	-1.860	2.210 **	-0.809	0.091 *	0.029	0.862	2.200	-0.075	0.043	0.030
		LFP4	-2.840	2.010 *	-1.560	0.103 *	0.078	0.457	3.160 *	-0.098	0.040	0.027
	b	LFP1	-1.020	0.844 **	-2.340	0.034	-0.044	4.020 **		0.002	0.040	0.029
		LFP2	-0.664	1.600 *	-2.480	0.064	-0.099	3.590		0.004	0.034	0.023
		LFP3	-0.818	2.010 *	-0.388	0.089 *	-0.129	2.520		-0.016	0.034	0.023
		LFP4	-1.310	1.730 *	-0.952	0.100	-0.148	2.830		-0.013	0.026	0.015
M2	a	LFP1	-1.150	0.622 **	-2.030	0.023	0.018	2.370 *	0.939 **	-0.021	0.044	0.031
		LFP2	-2.230	1.270 *	-2.700	0.054	0.038	2.490	1.940 **	-0.047	0.049	0.036
		LFP3	-2.740	1.700 *	-0.783	0.079 *	0.056	0.357	2.530 **	-0.080	0.046	0.033
		LFP4	-3.840	1.630 *	-1.640	0.088	0.101	0.099	3.490 **	-0.102	0.048	0.035
	b	LFP1	-0.722	0.538 *	-1.840	0.022	-0.050	3.080 **		0.005	0.034	0.022
		LFP2	-1.330	1.100 *	-2.320	0.052	-0.102	3.960		0.006	0.034	0.023
		LFP3	-1.550	1.480 *	-0.299	0.077 *	-0.126	2.260		-0.012	0.030	0.019
		LFP4	-2.150	1.320	-0.976	0.085	-0.148	2.720		-0.008	0.025	0.014
M3	a	LFP1	-1.150	0.720 **	-2.180	0.025	0.014	2.450 *	0.892 **	-0.019	0.040	0.027
		LFP2	-1.910	1.440 *	-2.700	0.056	0.035	2.390	1.880 **	-0.045	0.045	0.032
		LFP3	-2.310	1.910 **	-0.884	0.083 *	0.050	0.402	2.450 *	-0.078	0.043	0.030
		LFP4	-3.160	1.800 *	-2.110	0.093	0.092	-0.007	3.340 **	-0.094	0.042	0.029
	b	LFP1	-0.739	0.641 *	-2.000	0.024	-0.050	3.120 **		0.005	0.032	0.021
		LFP2	-1.030	1.270 *	-2.340	0.054	-0.101	3.800		0.006	0.032	0.021
		LFP3	-1.150	1.690 *	-0.415	0.081	-0.126	2.250		-0.012	0.031	0.019
		LFP4	-1.540	1.500	-1.470	0.090	-0.147	2.500		-0.004	0.024	0.013

Table 10: *Regression results from Model 1, Model 2 and Model 3, based on standardized explanatory variables. The sample period is from January 1 2004 to December 31 2013. ***, **, and * indicates significance at a 1%, 5% and 10% level, respectively, based on Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator.* $CONSD_t$ *is the total deviation in actual electricity consumption in Norway, Sweden, Denmark and Finland, from the average (2000–2013), in week t [MWh],* $INFD_t$ *is the deviation in actual inflow in Norway and Sweden from the average (1996–2013), in week t [MWh],* $WINDP_t$ *is the wind production in Denmark in week t [GWh],* $RESM_t$ *is the median reservoir level in Norway and Sweden (1995-2013) in week t [%],* $RESD_t$ *is the deviation in actual reservoir level in Norway and Sweden from median (*$RESM_t$*) in week t [%],* VAR_t *is the variance of hourly spot prices in week t,* S_t *is the spot price in week t [NOK/MWh].*

			CONSD	INFD		WINDP	RESM		RESD	VAR		S		R^2	$R^2(adj.)$
M1	a	LFP1	-0.052	0.135	**	-0.064	0.075	*	0.000	0.121	*	0.073		0.043	0.030
		LFP2	-0.037	0.162	*	-0.045	0.088		0.018	0.047		0.130	*	0.043	0.030
		LFP3	-0.037	0.167	**	-0.011	0.101	*	0.014	0.015		0.131		0.043	0.030
		LFP4	-0.051	0.135	*	-0.018	0.101	*	0.033	0.007		0.166	*	0.040	0.027
	b	LFP1	-0.041	0.127	**	-0.061	0.074		-0.042	0.137	**			0.040	0.029
		LFP2	-0.016	0.147	*	-0.040	0.086		-0.058	0.075				0.034	0.023
		LFP3	-0.016	0.152	*	-0.005	0.098	*	-0.062	0.043				0.034	0.023
		LFP4	-0.023	0.116	*	-0.011	0.097		-0.063	0.043				0.026	0.015
M2	a	LFP1	-0.059	0.120	**	-0.068	0.064		0.022	0.104	*	0.142	**	0.044	0.031
		LFP2	-0.066	0.142	*	-0.052	0.089		0.027	0.063		0.170	**	0.049	0.036
		LFP3	-0.063	0.147	*	-0.012	0.100	*	0.031	0.007		0.172	**	0.046	0.033
		LFP4	-0.078	0.124	*	-0.022	0.098		0.049	0.002		0.208	**	0.048	0.035
	b	LFP1	-0.037	0.104	*	-0.062	0.062		-0.061	0.135	**			0.034	0.022
		LFP2	-0.039	0.123	*	-0.045	0.085		-0.072	0.100				0.034	0.023
		LFP3	-0.035	0.127	*	-0.004	0.097	*	-0.068	0.044				0.030	0.019
		LFP4	-0.044	0.100		-0.013	0.094		-0.071	0.047				0.025	0.014
M3	a	LFP1	-0.053	0.126	**	-0.066	0.064		0.016	0.097	*	0.122	**	0.040	0.027
		LFP2	-0.052	0.149	*	-0.048	0.084		0.023	0.056		0.153	**	0.045	0.032
		LFP3	-0.049	0.155	**	-0.012	0.098	*	0.025	0.007		0.156	*	0.043	0.030
		LFP4	-0.060	0.128	*	-0.026	0.097		0.042	0.000		0.188	**	0.042	0.029
	b	LFP1	-0.034	0.112	*	-0.061	0.061		-0.055	0.124	**			0.032	0.021
		LFP2	-0.028	0.132	*	-0.042	0.081		-0.066	0.090				0.032	0.021
		LFP3	-0.025	0.137	*	-0.006	0.095		-0.064	0.041				0.031	0.019
		LFP4	-0.029	0.107		-0.018	0.093		-0.066	0.041				0.024	0.013

7. Conclusion

The conditions in the physical and financial market have changed considerably since Nord Pool was established, and the first financial contracts were offered. An increasingly volatile spot price, due to more extensive use of renewable energy sources, emphasize the need for a well-functioning and efficient financial market. Understanding the dynamics of the forward premium is important for all market participants. Our objective in this paper has been to explain the variation in the forward premium in the Nordic electricity market, using fundamental factors observed in the final week of trading.

Our findings suggest that the futures prices are biased predictors of future spot prices. We also find significant forward premium for all the examined contracts. The analysis show that the forward premium is largest during the winter and fall, and not significant during spring and summer.For the sake of robustness, we consider various definitions of the forward premium and find that various definitions result in consistent conclusions.

The most important determinat of the forward premium in the Nordic power market is the deviation of the inflow from the normal inflow level of that specific week of the year. Higher inflow implies higher forward premium. It is worth noting that most of of the electricity produced in Norway is produced from hydropower, and therefore it was expected that inflow will play a major role in explaining the premium.

Contrary to Botterud et al. (2010) and Weron and Zator (2014), we find no evidence of deviation in reservoir level to explain the premium. We find also that higher current spot price predicts higher risk premium. Higher variance in the spot price also induce higher forward premium, but only so for the contracts with shortest maturity of one weak.

The variables considered in this study can explain only small part of the forward premium and future research should examine the effects from other fundamental variables on th forward premium. Examples include weather-related variables, open interest, and general market volatility. Additionally, it would be interesting to examine how the various exogenous effects differ across the distribution of the dependent variable.

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