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The forecasting power of medium-term futures contracts

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(Received April 8, 2014, 2014; revised July 15, 2014, 2014; accepted July 16, 2014, 2014)

This study investigates whether weekly futures prices, covering the time period 1996–2013, are unbiased predictors of future spot price in the Nordic power market. The results give no clear evidence of bias in the futures prices, except for during the winter periods from 2003 to 2009. In these winters the futures prices overshoot the spot price, resulting in a positive risk premium. We find a significant premium during winter and fall, when analyzing the whole sample. There is no evidence of a premium during summer. Dividing the sample into two subperiods, 1996–2005 and 2006–13, we find the highest and most significant risk premium during winter in the first subperiod; in the latter subperiod, there is less evidence of a significant risk premium.

1 INTRODUCTION

The Nordic power market has been through several deregulations since its establishment in 1991. Futures and forward contracts are the main derivatives in the financial part of this market and are playing an increasingly important role in risk management and speculation in a highly volatile physical market. Power producers want to hedge their production, 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. Understanding the relationships between the spot and futures prices in general, and the forward premium in particular, is crucial for the participants in the market.

However, despite its importance, the research about the existence and behavior of forward risk premiums in electricity markets is not conclusive. Both the sign and the magnitude of the forward premium vary between studies and also within the same market. In this paper we use what is, to the best of our knowledge, the longest sample period ever examined for one of the largest and most important electricity exchanges in the world. We also extend previous research for this market by examining the relationship between forward and subsequent spot prices dynamically. We can thus provide evidence on how the forward premiums behave over time and, in particular, for different seasons of the year.

We study the forward risk premium for the Nordic market using weekly futures with holding periods of between one and six weeks. Our data set consists of almost seventeen years of data, from January 1996 to October 2013, representing 930 observations. Following Haugom and Ullrich (2012), we look at the realized risk premium, ie, the difference between the futures price and the spot price at delivery. This allows us to compare our results with previous studies (see, for example, Botterud *et al* 2010; Gjolberg and Brattested 2011; Haugom and Ullrich 2012; Lucia and Torró 2011; Weron and Zator 2013). We add to previous research by investigating whether there is evidence of a systematic risk premium in the futures prices, and whether the prices are unbiased predictors of spot price. By dividing the data sample into seasons, we examine whether any seasonal pattern is present. Sijm *et al* (2006) argue that the introduction of European Emission Trading Scheme (ETS) contracts in 2005 raised the spot price level in the Nordic market. Thus, we divide our data sample into two subperiods, ie, 1996–2005 and 2006–13, in order to examine the effect of a possible significant shift in the price level on the risk premium.

The remainder of this paper is organized as follows: Section 2 gives a short introduction to the physical and financial Nordic electricity market, with emphasis on futures contracts. In Section 3, we discuss the relationship between spot and futures prices, and define the risk premium. Section 4 reviews previous studies on relevant and related topics. Section 5 provides a preliminary data analysis. Section 6 presents

an empirical analysis of historical price data from Nord Pool and Nasdaq OMX. Section 7 concludes.

2 THE NORDIC ELECTRICITY MARKET

The Energy Act of 1990 aimed to restructure and liberalize the Norwegian power market. It came into effect on January 1, 1991. Market-based principles were introduced on both the production side and the consumption side, opening these up for competition. The goal was to increase efficiency and lower consumer prices. Through liberalization of the electricity market, risk was transferred from consumers to producers. Consumers were given freedom in the choice of power supplier.

The other Nordic countries went through similar deregulations in the following years. In 1996 Sweden became part of the Norwegian marketplace, and Statnett Marked AS was renamed Nord Pool ASA. This opened up trade across the national border. Finland joined in 1998, followed by Denmark in 2000. The result was the first international power exchange (Nord Pool Spot 2013c). Today, the Nordic electricity market consists of several independent entities. These are producers, network owners, system operators, consumers and traders.

2.1 The physical market

The power market providing physical delivery is organized through Nord Pool Spot.¹ Nord Pool Spot consists of a day-ahead market, Elspot, and an intraday market, Elbas. In 2012, 77% of all physical power trade in the Nordic and Baltic states was traded in the spot market (Nord Pool Spot 2013d). The rest was bilaterally traded. Three hundred and twenty-six participants from twenty different countries trade directly in the physical market through Nord Pool Spot, in addition to a large number of power producers (Carr 2012). The total power generated and consumed in the Nordic region (NordREG 2013) in 2012 amounted to 399 TWh and 387 TWh, respectively (371 TWh and 379 TWh, respectively, in 2011).

At Elspot, power sellers and buyers submit bids for next-day delivery. The system price is set through a double auction. This is the equilibrium price, found where the aggregated supply and demand curves cross, assuming no transmission restrictions (Nord Pool Spot 2013a).² Based on this, hourly prices are calculated for the following day.

¹ In 2010, the physical power trade also opened up for the Baltic countries.

² The area prices are decided in the same way, with total supply and demand in the given area. Thus, these prices will differ between geographical areas. Power flows from the low price areas to the high price areas until capacity limits are reached. This is seen as a shift in either the supply curve or the demand curve.

As market participants' predictions of supply or demand may be uncertain, intraday physical trade is possible through Elbas. Elbas makes it possible to trade power until one hour prior to delivery. Buyers and sellers can therefore adjust power sold or bought to meet their obligations. Consequently, power balance will be maintained (Nord Pool Spot 2013b).

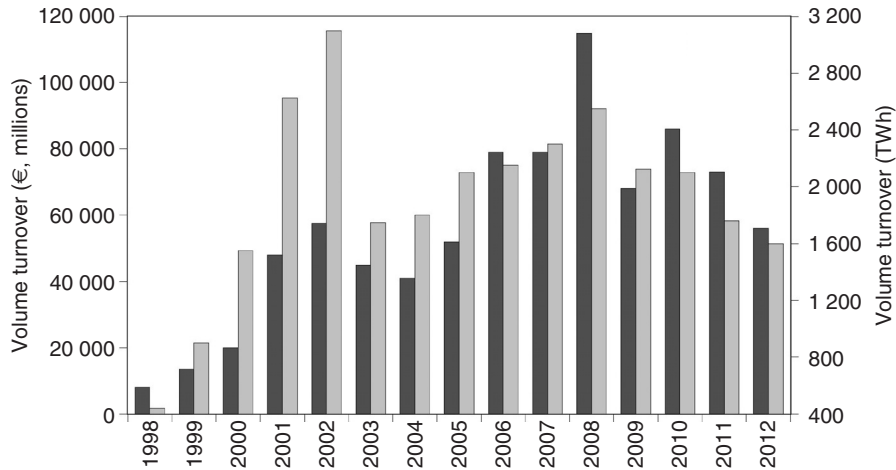
2.2 The financial market

The Nordic financial electricity market was previously known as Eltermin. After the market was acquired by Nasdaq OMX in 2010, it was renamed Nasdaq OMX Commodities Europe. Trading of cash-settled contracts has been offered since the beginning of 1995. These are used by producers, retailers and end users as risk management tools, and by traders who speculate on future spot prices. The derivatives comprise futures, forwards, contracts for difference and options with forward contracts as underlying assets. All of the futures and forward contracts use the system price as reference price. Nasdaq OMX Commodities Europe had 346 members as of 2012 (Carr 2012).

Initially, futures contracts had a time horizon of up to three years. After the introduction of cash-settled forward contracts in 1997, the time horizon was reduced to 8–12 months. More changes to the structure of the futures contracts were made in 2003. Since the liquidity was highest for the contracts closest to delivery, the horizon was further decreased to 8–9 weeks (Nasdaq OMX 2013c). This structural change of the contracts must be considered when analyzing price data (Veka 2013). Today, futures contracts are available for the next 3–9 days and the next six weeks (Nasdaq OMX 2013c). Forward contracts are available for the next six months, the remaining quarters of the current year and quarters of two rolling years, and ten future years (Nasdaq OMX 2013b). There is low liquidity for contracts with long holding periods. In the case of zero trades, the bid and ask prices are set by market makers, and there will not be a closing price corresponding to the last trade as for the other traded contracts. In this case, the closing price is calculated as the average of the bid and ask prices (Nasdaq OMX 2013c).

Since the payoff of the futures and forward contracts is calculated as the difference between the price of the contract and the system price over a period of time, these contracts act as swaps (Benth and Koekebakker 2008). Sanda *et al* (2013) show that yearly contracts dominate the traded derivatives among producers.

All contracts with delivery prior to 2006 were posted in Norwegian kroner (Nkr). After this, contracts were traded in euro. The intuition behind the decision was to make cross-border trade easier, in addition to the contracts becoming more standardized in comparison to similar products on other exchanges (Nasdaq OMX 2013a).

FIGURE 1 Value and volume turnover for the Nordic financial market from 1998 to 2012.

Dark gray bars show value turnover. Light gray bars show volume turnover.

The development in volume and value turnover from 1998 to 2012 is shown in Figure 1 on the facing page. The number of transactions has decreased from more than 200 000 transactions in 2008, to 143 375 in 2012 (NordREG 2013). During the last decade, the churn ratio³ has had an average value of 6 in the Nordic power market, with slightly decreasing values the past few years, confirming the same pattern (Carr 2012).

Carr (2012) finds that the liquidity decreased during the last couple of years, but emphasizes that the fall in liquidity is due to a reduction in the number of speculative players in the market following the financial crisis. Typically, there are constraints imposed on traders when it comes to risky investments. High short-term volatility due to the prevalence of renewable energy sources makes the power prices volatile. For instance, wind energy phased into the grid can result in electricity prices close to zero in windy periods (Carr 2012). This volatility effect became particularly evident as markets became more integrated. Grid improvements are necessary to reduce this volatility and price differences between areas.

3 THE RELATIONSHIP BETWEEN SPOT AND FUTURES PRICES

Fama and French (1987) elaborate on two different models for futures pricing of commodities. The first model is known as the theory of storage, while the second

³ The churn ratio is the ratio of total traded volume to consumed volume.

model explains the futures price as the sum of the expected spot price and a risk premium. The latter model is the most often applied. The theory of storage applied to futures pricing considers the basis, ie, the difference between spot and futures prices at a specified point in time, and is based on the argument of no-arbitrage between the spot and futures market. The basis can therefore be explained as interest forgone by storing a commodity, plus storage costs and convenience yield on inventory, ie, the benefit of holding inventory. Even though electricity is a nonstorable commodity, Botterud *et al* (2010) find evidence of a convenience yield in the futures prices in the Nordic electricity market. This is represented by water stored in reservoirs. Stored water may be used by producers to meet unexpected electricity demand, and the producers can take advantage of the accompanying high electricity prices. In the same setting, the storage cost is interpreted as the cost of water overflow. Weron and Zator (2013) study a longer price series and find limited support for the theory of storage in the data. As consumers are not able to store electricity, the common conclusion is that cost-of-carry relationships between spot and futures prices do not exist.

3.1 *Ex ante* and *ex post* risk premiums

In the second model, Fama and French (1987) explain the basis as the sum of the expected risk premium and the expected change in the spot price. Thus, we can express the basis as

$$F_{t,T} - S_t = \text{RP}^{\text{ea}} + E_t[S_{t+T} - S_t]. \quad (3.1)$$

$F_{t,T}$ is the time- t futures price with delivery period T , and S_t is the spot price at time t . RP^{ea} is the expected, or *ex ante*, risk premium, ie, $\text{RP}^{\text{ea}} = F_{t,T} - E_t[S_{t+T}]$. The basis gives us the bias of the futures price as a prediction of the time- $t + T$ spot price. Hence, it is also referred to as the futures bias.

We use the following definition of the realized, or *ex post*, risk premium:

$$\text{RP}^{\text{ep}} = F_{t,T} - S_{t+T}, \quad (3.2)$$

where $F_{t,T}$ is the futures price on the last trading day of week t for delivery in week $t + T$, and S_{t+T} is the average spot price in the delivery week. The *ex post* risk premium is equal to the *ex ante* risk premium plus the deviation of the realized future spot price from the expected future spot price:

$$\text{RP}^{\text{ep}} = \text{RP}^{\text{ea}} + E_t[S_{t+T}] - S_{t+T}.$$

A positive premium implies that the producers earn a premium when selling futures contracts. We also investigate the log *ex post* risk premium, LRP^{ep} , given by

$$\text{LRP}^{\text{ep}} = \ln F_{t,T} - \ln S_{t+T}. \quad (3.3)$$

The log transformation makes the Gaussian distribution a better approximation, which implies that standard ordinary least squares (OLS) techniques can be used.

Previous studies analyze the basis (see, for example, Gjolberg and Johnsen 2001; Lucia and Torró 2011; Redl and Bunn 2013). As seen from (3.1), the basis gives information on the expected risk premium in addition to the expected change in the spot price. The *ex ante* risk premium is investigated by, for example, Botterud *et al* (2010) and Bessembinder and Lemmon (2002). However, the expected spot price at delivery is hard to measure, and the results in these studies depend on the model applied. Consequently, such studies may not be comparable. When the realized risk premium is used, as in Lucia and Torró (2011), Gjolberg and Brattested (2011), Haugom and Ullrich (2012) and Weron and Zator (2013), it is assumed that the difference between the expected spot price and realized spot price acts as noise. The realized premium will then equal the sum of the expected risk premium and a noise term:

$$F_{t,T} - S_{t+T} = \text{RP}^{\text{ea}} + \varepsilon_{t,T}.$$

Redl and Bunn (2013) point out that it is difficult to know how much of the realized premium is due to the price of risk, and how much is due to the forecast error.

4 EARLIER FINDINGS ON THE RELATIONSHIP BETWEEN SPOT AND FUTURES PRICES

There are an increasing number of papers addressing the relationship between spot and futures prices. The papers reviewed include research on several electricity markets, eg, PJM, European Energy Exchange (EEX) and Nord Pool. The data sets (of different lengths) analyzed consist of spot and derivatives prices between 1996 and 2010.

Bessembinder and Lemmon (2002) develop an equilibrium model for electricity forward prices based on the assumptions that the demand and supply sides are risk averse, and that electricity cannot be stored. They argue that the forward premium is a function of the variance and skewness of the spot price. The variance (skewness) should have a negative (positive) influence on the premium. Botterud *et al* (2010) criticize the model and argue that it cannot be transferred to a hydro-dominated market like the Nordic one, because of its simplifying assumptions. The model assumes no speculators, a fixed retail price for the load-serving entities and that each producer has a fixed convex cost function.

Longstaff and Wang (2004) analyze the forward premium⁴ in the PJM electricity market between 2000 and 2002, using hourly spot and day-ahead forward prices. They

⁴ Longstaff and Wang (2004) define the forward premium as $\text{FP}_{it} = E_t[F_{it} - S_{i,t+1}]$, where F_{it} is the electricity forward price observed on day t for delivery during hour i of day $t + 1$, and $S_{i,t+1}$ is the spot price for hour i of day $t + 1$.

find a significant positive forward premium in the data, although it changes with the time of day. Their analysis provides support for the model presented by Bessembinder and Lemmon (2002).

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. Their results indicate that the short-term forward prices are unbiased predictors of the future spot price. Further, they find that including additional publicly known information in the regression model does not improve the forecast of spot prices. They conclude that market efficiency has increased, the risk premium has decreased or both, as the agents have gained experience. In addition, they find no support for the Bessembinder and Lemmon (B&L) model in the data. Several papers arrive at the same conclusion for the B&L model in the Nordic market (see, for example, Botterud *et al* 2010; Lucia and Torr o 2011; Redl *et al* 2009).

Botterud *et al* (2002) were among the first to provide empirical evidence of a risk premium in the Nordic market. Their data set consists of observations between 1996 and 2001, for contracts with 1, 4, 26 and 52 weeks to delivery. The delivery period ranges from one week to one season. They find significant and positive risk premiums, and also reveal that the magnitude increases with the length of the holding period. This was later confirmed by Gjolberg and Johnsen (2001), Mork (2006), Weron (2008) and Redl *et al* (2009). Redl *et al* (2009) conclude that this may be due to supply and demand shocks, while not ruling out market inefficiency. In addition, Botterud *et al* (2002) try to explain the premium by looking at deviations from normal reservoir levels. They plot observations on spot and futures prices and reservoir levels, and use visual inspection to identify a relationship. Botterud *et al* (2010) inspect this relationship further: they use OLS regression and find reservoir level, deviation in hydro inflow and demand to be significant explanatory variables. By studying weekly futures with 1–6 weeks to delivery, they find futures prices between 1996 and 2006 to be on average 1.3% (one-week contract) to 4.4% (six-week contract) above the spot price. Botterud *et al* (2010) argue that the theory of storage applies to a hydro-dominated market, due to the possibility of water storage in reservoirs. They find evidence that storage cost and risk premium increase with the reservoir level, as there is a higher probability of water overflow.

Weron and Zator (2013) study a thirteen-year time series (1988–2010) of spot and futures prices in the Nordic market. They use regression models with generalized autoregressive conditional heteroscedasticity (GARCH) residuals, and consider the potential pitfalls of applying OLS regression to calculate the risk premium.⁵ Their

⁵ These potential pitfalls are the simultaneity problem, the effect of correlated measurement errors and the impact of seasonality on the regression results (see Weron and Zator (2013) for more details).

analysis contradicts the results of Botterud *et al* (2010), finding the impact of reservoir level on the risk premium to be negative.⁶ They argue that low reservoir levels will increase the futures demand, as the probability of spikes in the spot price increases. Weron and Zator (2013) also show that, by taking the seasonality of the reservoir level into account, the storage theory proposed by Botterud *et al* (2010) only has limited support in the data.

Lucia and Torró (2011) repeat the study of Botterud *et al* (2010), looking at weekly futures with a time to delivery of 1–4 weeks in the period from 1998 to 2007. They analyze the whole sample period, and a sample excluding the supply shock during winter 2002–3,⁷ in addition to studying the pre- and post-shock data. 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 fall and winter. Their analysis provides evidence that futures prices were mainly based on risk considerations, in addition to supporting the B&L model, prior to the supply shock. However, they find evidence that circumstances changed after the shock: the spot price increased and the seasonal pattern faded away.

Gjolberg and Johnsen (2001) analyze monthly 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 easily accessible information improves the forecasts of the spot price. Gjolberg and Johnsen (2001) point out a possible abuse of market power from the producers' side, but have no statistical evidence to support this.

Gjolberg and Brattested (2011) argue that if the forecast error is a risk premium, it should follow a seasonal pattern based on expected risk expectations. Bessembinder and Lemmon (2002) and Haugom and Ullrich (2012) find that the premium in the US market is greatest during summer. In the Nordic market, Lucia and Torró (2011) find a substantial risk premium during winter and a zero premium during summer. Botterud *et al* (2010) find that the premium has a less distinct seasonal pattern than the spot price. Analyzing variations in the forecast error by season over the period from 1995 to 2008, Gjolberg and Brattested (2011) find that seasonality in general explains little. Still, they find the error to be greatest in the winter months (December, January and February) and midsummer (June and July), when analyzing the forecast error by calendar month. Gjolberg and Brattested (2011) conclude there are highly significant forecast errors, and their magnitude can hardly be explained by the level

⁶ Weron and Zator (2013) find the impact to be positive, but, according to our definition of the risk premium, this corresponds to a negative impact.

⁷ In 2002, water reservoirs were well above normal during the summer. Thus, power producers started to draw down water reservoirs to make room for the fall precipitation. The expectations on water inflow were not met and the reservoir levels fell far below its normal values, making the spot prices increase to extreme levels. This is known as the Nordic supply shock.

of risk alone. They point out that the premium may be explained simply as a peso problem,⁸ although this is not likely.

Veka (2013) uses a sample of daily observations between 2006 and 2012. This extends the work by Gjolberg and Brattested (2011), as it uses contracts with a broader time to delivery, additional explanatory variables and more recent data. Veka finds that there may exist structural or informal barriers preventing outside speculators from entering the financial market. He also finds evidence of a positive forward premium, but that this shows no clear seasonal pattern, confirming the results of Gjolberg and Brattested (2011) and Botterud *et al* (2010). Veka (2013) finds neither systematic risk nor strong dependence between the premium and the implied volatility of the contracts, but finds indications of tail dependence with negative returns in the equity market. Based on this, he concludes that the premium may include some element of risk, but it is still hard to explain the magnitude from risk alone.

Gjolberg and Johnsen (2001), Redl and Bunn (2013) and Gjolberg and Brattested (2011) argue that the size of the risk premium may give indication of market power among producers. Still, Fridolfsson and Tangerås (2009) find no evidence of market power in their empirical studies of the Nordic power exchange. Amundsen and Bergman (2006) argue that use of market power in a hydropower-dominated market is hard to detect, and convincing evidence is lacking. They claim that the flexibility in the choice of power suppliers and the “public service attitude” in the Nordic power companies have reduced the possibility of market power abuse.

Probably the main reason why research about the forward risk premium is not conclusive is that different studies use different data sets. The aforementioned papers study different markets, different time periods, different contracts (weekly, monthly, etc) and different futures positions (front position, second position, etc). Another reason is that risk premium can vary over time, both over the long-term (as the market matures, the risk premium might diminish) and over the short-term horizon (eg, due to different market conditions during the summer and during the winter).

Our paper contributes to the research about the futures risk premiums in all the above areas. We study the Nord Pool market, which gives us several advantages. It is one of the oldest and most developed electricity markets in the world, meaning that our data spans longer time periods than any previous study. Moreover, findings from this market are less likely to be affected by transitory effects due to the infancy of the market. However, since the market nevertheless evolves continuously, we also study how the risk premium evolves over time. Moreover, we study the impact of the seasons of the year on the risk premium.

⁸ Market participants strongly believe that the spot price will rise dramatically as a reaction to, for example, cold weather or a dry year, and hedge against the expected high prices. If this event finally occurs after some time, the market has been “wrong” for a longer period. However, it is not irrational to hedge against events that may take place in the future.

TABLE 1 Descriptive statistics for the weekly spot price.

	Whole sample period					Specific sample periods	
	All	Winter	Spring	Summer	Fall	1996–2005	2006–13
Mean	248.84	280.95	244.23	216.33	254.40	187.41	327.49
SE	3.91	8.47	7.48	6.69	8.01	3.74	5.43
SD	119.10	128.70	114.92	102.41	121.20	85.35	109.61
Minimum	39.08	99.55	75.24	39.08	48.45	39.08	62.14
Median	239.43	253.88	237.58	223.32	247.99	179.58	316.01
Maximum	751.72	751.72	714.01	481.03	613.37	751.72	714.01
Skewness	0.85	1.17	0.84	0.14	0.74	1.68	0.50
Excess kurtosis	0.94	1.32	0.79	−0.91	0.11	7.51	0.52

Winter is defined as the delivery week from 47 to 7, and the other seasons are defined by the subsequent 13 week periods. Statistics for the subperiods 1996–2005 and 2006–13 are also reported. All prices are in NKr/MWh. SE denotes standard error. SD denotes standard deviation.

5 DATA AND PRELIMINARY ANALYSIS

The data set of spot prices is obtained from Nord-Trøndelag Elektrisitetsverk AS (NTE) and consists of daily system prices in NKr, starting on January 1, 1996 and ending on October 13, 2013. We generate a time series of weekly prices using the arithmetic average of daily spot prices from Monday to Sunday. The spot prices have also been divided into seasons,⁹ which allows us to investigate seasonal dynamics. The weekly futures prices cover the same period,¹⁰ and are the closing prices on the last day of trading¹¹ (see Section 3.1).

We have included specific sample periods, ie, 1996–2005 and 2006–13, in the analysis. Veka (2013) argues that the period from 2006 will represent the current Nordic market the best, due to the introduction of new contract standards and euro-quoted contracts¹² (see Section 2.2). On the other hand, Lucia and Torró (2011) use data from 1998, ie, excluding the first two years of futures data. They base their decision on two arguments. First, they want to avoid the initial period where the market was undergoing changes in the trading system and contractual conditions. Second,

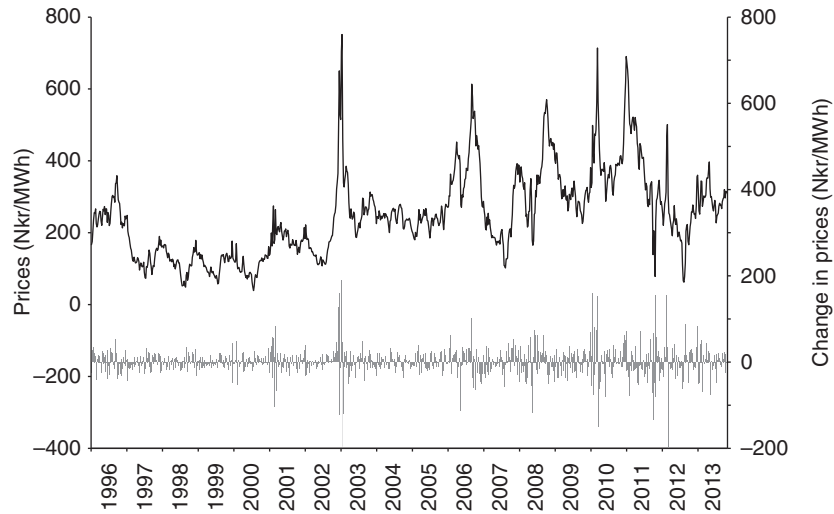
⁹ Winter is defined as weeks 47 to 7. The other seasons are defined using consecutive 13-week periods.

¹⁰ The futures prices were obtained from Tarjei Kristiansen and Trønder Energi.

¹¹ Redl *et al* (2009) and Redl and Bunn (2013) find that, when using futures price on the last trading day instead of monthly averages in the last trading month, the forecast error is smaller.

¹² Starting from 2006, all contracts are quoted in euro. We use the daily exchange rates from Norges Bank to convert the futures prices to NKr (Norges Bank 2013). There might be a small bias in the data set, as NTE uses a different exchange rate to convert the futures prices from euro to NKr. This is not discussed further, but worth mentioning.

FIGURE 2 Weekly system price (black line, left-hand scale) and changes in weekly system price (gray line, right-hand scale) for the period from 1996 to 2013.



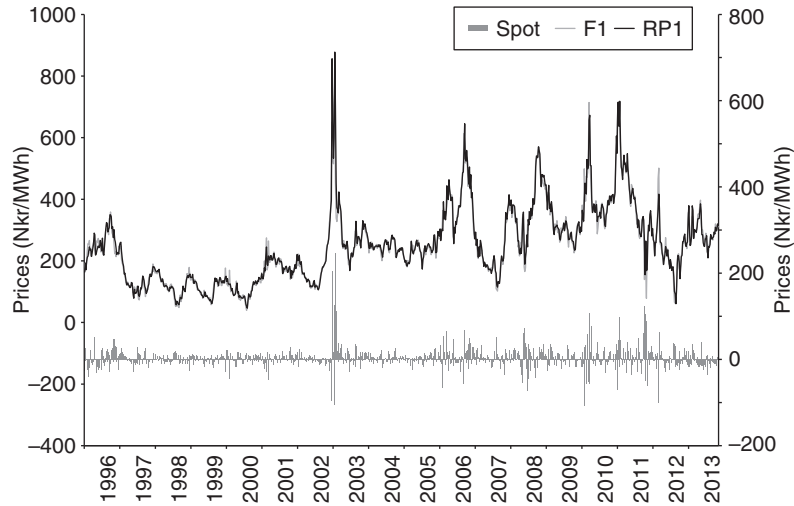
they want the market to be complete, which they consider it to be after Finland joined Nord Pool in 1998. We claim that the market underwent important structural changes after 1998, eg, the number of participants in the financial power market has increased (NordREG 2011), and the contract standards have changed further. Thus, we consider the complete data period to represent the dynamics at least as well as the data period excluding the first two years.

The descriptive statistics for the entire period are shown in Table 1 on the preceding page. The table also contains statistics computed by season and for the subperiods. The spot price and its changes are plotted in Figure 2.

The mean spot price is 248.84 Nkr/MWh for the entire sample. We observe the highest mean price during winter (280.95 Nkr/MWh), and the lowest during summer (216.33 Nkr/MWh). This is as expected in a Nordic climate. Figure 2 indicates a seasonal pattern in the first few years, ie, high spot prices during winter and low prices during summer. However, the pattern is not as distinct in the years following 2003. The extreme spot prices during winter 2002–3 represent the Nordic supply shock. We observe an increase in spot price level after 2003, and then again in the period after 2005. Sijm *et al* (2006) find that the introduction of the ETS explains much of the increase in spot prices after 2005.¹³ The market experienced high spot

¹³ The introduction of the ETS in 2005 changed the cost structure for the power producers to account

FIGURE 3 Weekly spot prices and prices of the one-week futures contracts.



The risk premium, defined in (3.2), for the one-week contract is plotted for comparison. The sample size consists of 928 observations, and ranges from January 1, 1996 to October 13, 2013. The spot and futures price (F1) use the left-hand scale, and the risk premium (RP1) uses the right-hand scale.

TABLE 2 Correlation between the spot price and the futures contracts with holding periods from one to six weeks.

	F1	F2	F3	F4	F5	F6
Whole sample	0.981	0.944	0.914	0.889	0.862	0.838
1996–2005	0.974	0.917	0.880	0.851	0.813	0.773
2006–2013	0.973	0.917	0.864	0.819	0.771	0.734

The whole sample period is from January 1, 1996 to October 13, 2013. The correlation between the spot price and the futures contracts for the different subperiods is also reported in the table.

prices in 2010, which was a dry year with low reservoir levels. The deficit in reservoir levels reached a maximum value of 30 TWh (NordREG 2011). An increase in average temperatures in 2011–12 caused the prices to plummet to lower levels.

The spot price is highly volatile, with a standard deviation of 119.10 Nkr/MWh for the entire sample. Winter has the highest volatility, of 128.70 Nkr/MWh, and the lowest volatility is experienced during summer (102.41 Nkr/MWh). The extreme volatility is well-documented in the literature (see, for example, Gjolberg and Johnsen

for carbon emissions. In an integrated market, this will influence the water values and the scheduling of hydro resources.

2001; Lucia and Schwartz 2002; Lucia and Torr  2011; Weron and Zator 2013). The excess kurtosis (0.94) in the sample reflects the frequent spikes in spot prices. We notice a positive skewness in the sample, which indicates a more frequent occurrence of positive spikes in the spot price. The excess kurtosis for winter is 1.32, indicating that extreme values are more likely to occur during winter. The summer statistic has a negative value (−0.91), which implies the opposite. The skewness is close to zero for summer, which suggests an approximately equal probability of spikes in both directions.

We have computed similar statistics for the futures as we did for the spot price. The futures prices exhibit many of the same features as the spot price. Due to space considerations we just briefly summarize the findings without presenting the tables here.

Figure 3 on the preceding page plots the spot price and the futures price with a holding period of one week. The contract with one week to delivery follows the spot price closely throughout the entire sample.

The decrease in correlation between spot and futures prices is shown in Table 2 on the preceding page. The difference in correlation is most evident for the last four contracts (F3–F6). The correlation for the first subperiod ranges from 0.88 to 0.77 for F3 to F6, and from 0.86 to 0.73 for the latter subperiod.

The volatility increases with the holding period. For the whole sample, the contracts with holding periods of one, three and five weeks have deviations of 23.56, 50.33 and 63.34 Nkr/MWh, respectively. The increase is related to higher uncertainty for longer holding periods. For all contracts, the standard deviation has increased from the first to the latter subperiod. This is due to higher spot price volatility.

The skewness for the whole sample decreases as the holding period increases. The skewness is particularly high during winter in the first subperiod, as this period includes the supply shock.

The excess kurtosis for the whole sample is highest for contracts with one and two weeks to delivery (23.13 and 25.01, respectively) and it decreases as the length of the holding period increases. It is highest during winter for contracts with holding periods of one to four weeks, as a natural consequence of extreme risk premiums arising this time of year.

6 EMPIRICAL ANALYSIS OF THE NORD POOL MARKET

In this section, we perform OLS regression with rolling and recursive estimation of the regression coefficients. This allows us to investigate how the coefficients vary

over time.¹⁴ We test the unbiased forward rate hypothesis on the whole sample and the seasons separately.

6.1 Unbiased forward rate hypothesis

The unbiased forward rate hypothesis (UFH) can be used to test whether futures prices are unbiased predictors of future spot prices. The UFH gives the spot price at time $t + T$ as

$$S_{t+T} = \alpha + \beta F_{t,T} + \varepsilon_{t+T}. \quad (6.1)$$

The null hypothesis states that futures prices are unbiased forecasts of future spot price. From (6.1), this corresponds to $\alpha = 0$ and $\beta = 1$, and uncorrelated residuals with a mean value of zero. The market is then said to be efficient. We assume, like Haugom and Ullrich (2012), that an alpha significantly different from 0 provides evidence of a systematic premium, and a beta significantly different from 1 gives evidence of a forecast error.

As spot prices tend to experience spikes, we choose to do the UFH regression using the natural log of futures and spot prices to make the distributions smoother. We obtain the following expression:

$$\ln S_{t+T} = \alpha + \beta \ln F_{t,T} + \varepsilon_{t+T}. \quad (6.2)$$

The regression results are shown in Table 3 on the next page. Considering the whole sample, there is weak evidence of a systematic risk premium for futures contracts with holding periods of five and six weeks. The same contracts are also biased predictors of the subsequent spot (significant at the 5% level), while there is weaker evidence (significant at the 10% level) of bias in the futures prices for contracts with holding periods of three and four weeks. Contracts with longer times to maturity are the least liquid and may therefore also contain a liquidity premium (see Section 2.2).

No patterns related to significant alpha and beta values are revealed for seasons. However, we note that the coefficients for the one-week futures are closest to their null hypothesis values. Another interesting finding is that alpha for summer is negative, while beta is greater than 1, although neither are significant. Alpha and beta for winter deviate the most from their null hypothesis values, but are only significant for contracts with long holding periods.

R^2 estimates are highest for the futures contracts closest to delivery, which is to be expected. As the residuals are autocorrelated, the standard errors in the rolling and recursive regression are based on the Newey–West heteroscedasticity and autocorrelation consistent (HAC) covariance matrix estimator.

¹⁴ The recursive estimation allows us to study the long-term picture of how the parameters behave, while the rolling estimation gives a short-term picture.

TABLE 3 Tests of unbiased forward rate hypothesis on logarithmic prices, defined in (6.2), using OLS regression. [Table continues on next page.]

(a) Whole sample						
	1	2	3	4	5	6
α	0.037	0.122	0.182	0.239	0.298*	0.348*
β	0.991	0.972	0.959*	0.948*	0.937**	0.927**
R^2	0.970	0.918	0.875	0.843	0.845	0.791
$Q(10)$	46.45***	256.50***	551.57***	836.19***	1103.60***	1380.00***
(b) Winter						
	1	2	3	4	5	6
α	0.134	0.213	0.310	0.478	0.644	0.780**
β	0.973	0.954	0.935	0.904	0.873*	0.849**
R^2	0.964	0.898	0.833	0.773	0.716	0.666
$Q(10)$	10.46	40.00***	125.96***	214.04***	264.75***	308.71***
(c) Spring						
	1	2	3	4	5	6
α	0.051	0.176	0.258*	0.261	0.301	0.393*
β	0.989	0.964*	0.948*	0.946	0.938	0.921*
R^2	0.980	0.935	0.900	0.876	0.856	0.824
$Q(10)$	45.83***	78.32***	110.77***	142.96***	174.81***	210.43***

6.2 Rolling estimation

We perform rolling estimation on the whole sample using a window size corresponding to one year of data, ie, fifty-two observations. The window size for the seasons corresponds to one-and-one-half years of data, ie, twenty observations. By choosing one-and-one-half seasons, we escape the problem of a few seasonal observations from a different year contaminating¹⁵ the sample, as could be the case with a window size of one year. The window is kept constant and moves one week at a time. Figure 4 on page 18 plots the results from the regression on (6.2) with rolling estimation of the parameters, on futures contracts with holding period of one week. The confidence bands reflect two standard errors in each direction. The plots reveal highly time vary-

¹⁵ By choosing a window of one-and-one-half years we exclude the possible extreme variations in the price level between different years. The result will be smoother time series.

TABLE 3 Continued.

(d) Summer						
	1	2	3	4	5	6
α	-0.071	-0.048	-0.053	-0.043	-0.052	-0.064
β	1.013	1.005	1.004	1.001	1.002	1.004
R^2	0.970	0.918	0.880	0.855	0.835	0.827
$Q(10)$	67.35***	108.42***	150.95***	197.09***	205.43***	231.77***
(e) Fall						
	1	2	3	4	5	6
α	0.046	0.150	0.243	0.340	0.416	0.452
β	0.988	0.966	0.947	0.929	0.915	0.908
R^2	0.960	0.903	0.857	0.824	0.416	0.452
$Q(10)$	27.36***	44.46***	102.20***	131.36***	177.84***	216.64***

The sample period is from January 1, 1996 to October 13, 2013. Winter is defined as the delivery week from 47 to 7, and the other seasons are defined by the subsequent 13-week periods. The columns reflect holding periods from one to six weeks. $Q(10)$ is the Ljung–Box Q -statistic using ten lags. *, ** and *** denote statistical significance at the 1%, 5% and 10% confidence levels, respectively, based on the Newey–West heteroscedasticity and autocorrelation consistent covariance matrix estimator. The asterisks on $Q(10)$ reflect significance based on the χ^2 test statistic. The null hypothesis is $\alpha = 0$ and $\beta = 1$.

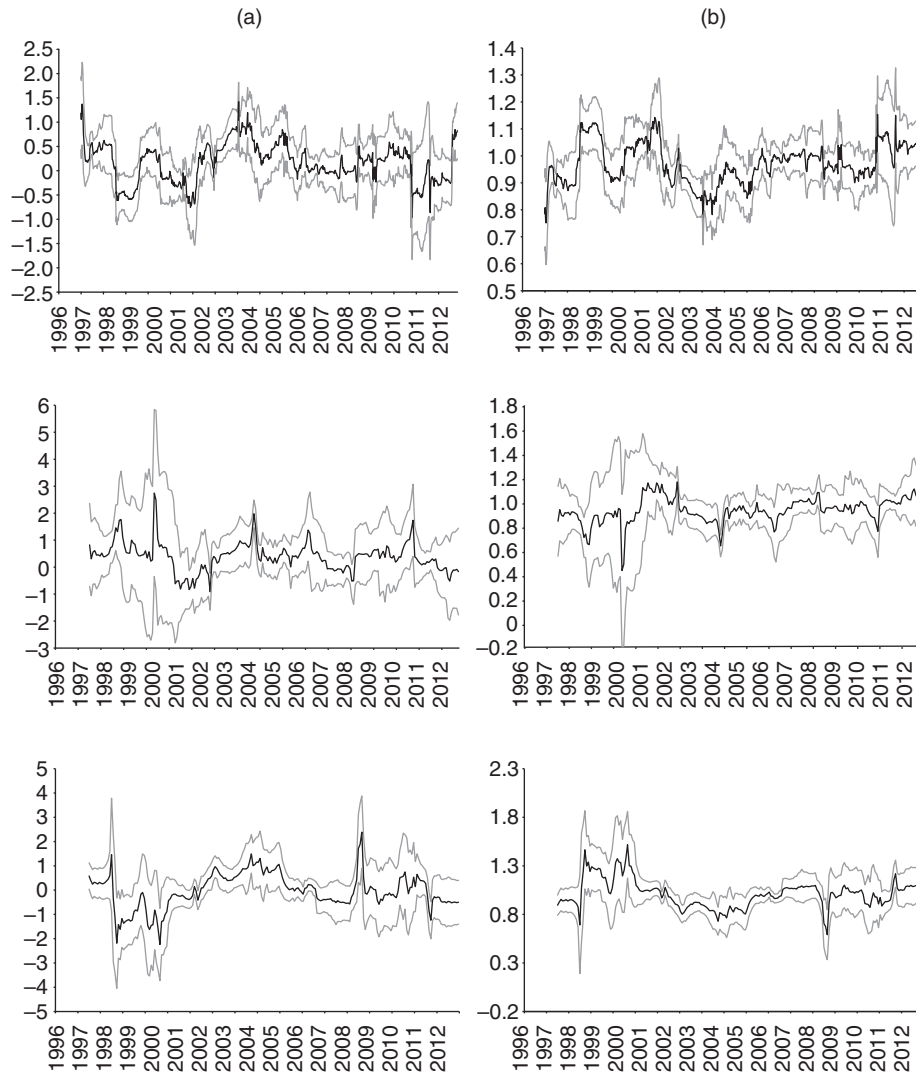
ing coefficients throughout the entire time period, without any clear pattern. For the whole sample, R^2 varies correspondingly, with values ranging from 0.61 to 0.99. We observe the same lack of pattern for the seasons.

A mature market should produce stable estimates for alpha and beta. For the whole sample, we observe highly unstable parameters in the period from 1996 to 2002, the period from late 2002 to 2005 and the period from late 2010 to 2013. We believe the variation in the first period is caused by an immature market, where participants are uncertain about the correct price of the contracts. The variation in the last period is caused by extremely high and low spot prices. Still, for both periods the parameters do not significantly differ from their null values. Alpha and beta for the second period significantly differ from 0 and 1, respectively. Alpha is greater than 0, ie, the producers earn the premium. Beta is less than 1, making the futures price a biased predictor of subsequent spot price. This period had extremely high spot prices, which caused a high demand for futures contracts.¹⁶

We observe that the parameters are more unstable during winter than during summer, but neither differ significantly from their null hypothesis values. Note that, prior

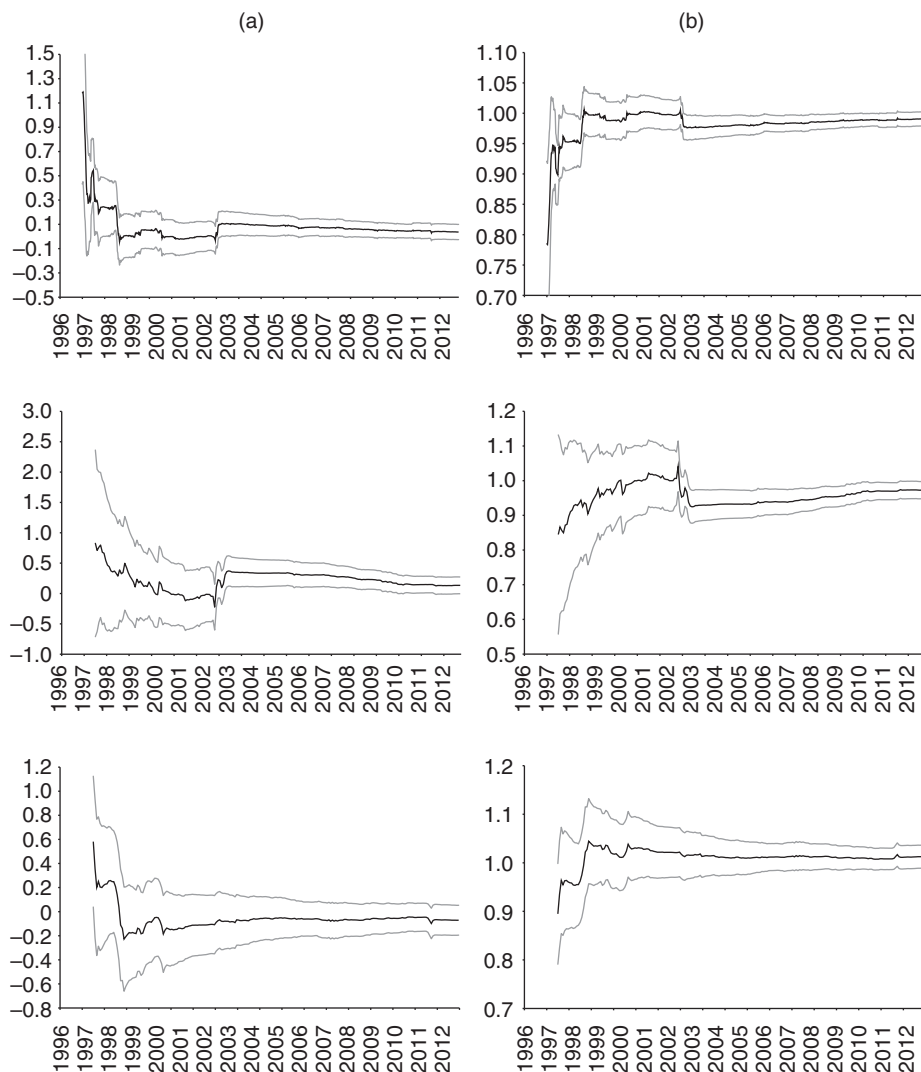
¹⁶ This period includes the Nordic supply shock.

FIGURE 4 Tests of unbiased forward rate hypothesis on logarithmic prices, defined in (6.2), using OLS regression with rolling estimation of the coefficients.



The holding period for the futures contracts is one week. The window size is fifty-two weeks for the whole sample and twenty weeks for the seasons. Gray lines denote ± 2 standard error. Black line denotes (a) alpha, (b) beta. The standard errors are based on Newey–West heteroscedasticity and the autocorrelation consistent covariance matrix estimator, and reflect significance levels of 95.4%. The whole sample period (top row) is from January 1, 1996 to October 13, 2013. Winter (middle row) is defined as the delivery week from 47 to 7 and summer (bottom row) is defined as the delivery week from 21 to 33.

FIGURE 5 Tests of unbiased forward rate hypothesis on logarithmic prices, defined in (6.2), using OLS regression with recursive estimation of the coefficients.



The holding period for the futures contracts is one week. The window size is fifty-two weeks for the whole sample, and twenty weeks for the seasons. Gray lines denote ± 2 standard error. Black line denotes (a) alpha, (b) beta. The standard errors are based on Newey–West heteroscedasticity and autocorrelation consistent covariance matrix estimator, and reflect significance levels of 95.4%. The whole sample period (top row) is from January 1, 1996 to October 13, 2013. Winter (middle row) is defined as the delivery week from 47 to 7 and summer (bottom row) is defined as the delivery week from 21 to 33.

to the winter of 2002, alpha and beta behaved differently for the winter and summer seasons. That is, when the parameters increased or decreased during winter, they did the opposite during summer. This provides support for seasonality prior to the supply shock. Another explanation is an immature market. After 2002, the movements in the parameters estimates are more similar.

6.3 Recursive estimation

The recursive estimation starts with a window size of one year for the whole sample, and one-and-one-half years for the seasons. The window size is increased with one week for each iteration.

Figure 5 on the preceding page plots the results from the OLS regression on (6.2), using recursive estimation of the coefficients, on futures contracts with a holding period of one week. It includes plots of the whole sample, and winter and summer periods, and reveals that the coefficients differ significantly from their null hypothesis values for the winter period. In this case there is evidence of producers earning a risk premium. Following the supply shock in late 2002, ie, in the period from 2003 to 2009, alpha is significantly greater than 0. We also find futures prices to be biased predictors of future spot price in the same period, ie, beta is significantly less than 1. Due to the high price levels during winter, the futures price will overshoot the spot price, causing a positive risk premium. In the opposite case, ie, at low price levels, the futures price will undershoot the spot price (Gjolberg and Brattested 2011). After 2009, the coefficients converge back toward their null values.

We observe highly unstable parameters in the first period of the sample, ie, from 1996 to 1998 for the whole period, and somewhat longer for the seasons.¹⁷ It is evident from the plots that the supply shock had an impact on the estimates. For winter, we observe a distinct upward shift in the estimate and the confidence bands for alpha. A shift in the opposite direction applies to beta. The shift in the parameters for the whole period most likely originates from the winter shift. We also notice a small shift for spring and fall, while the summer estimates are unaffected.

7 CONCLUSION AND FURTHER RESEARCH

This paper investigates whether futures prices are unbiased predictors of future spot price. We apply recursive and rolling estimation of the coefficients in the unbiased forward rate hypothesis. The data used is weekly observations from 1996 to October 2013. The main contribution of our study is that, unlike other studies, we do not assume that risk premium is constant, but rather assume that it can vary, particularly over the seasons of the year as well as gradually over the period.

¹⁷ This is partly due to small sample sizes.

We find no evidence of market inefficiency in the period analyzed. However, during winter in the period from 2003 to 2009, we find the futures prices to be biased predictors of the subsequent spot prices. This can be related to the high price level during winter, where the futures prices tend to overshoot the spot price. After 2009, the futures prices converge toward being unbiased predictors of the spot prices.

A general finding is that the supply shock during winter 2002–3 had an impact on the spot and futures prices. This particular event is decisive for many of the descriptive statistics provided for the period from 1996 to 2005.

Descriptive analysis of the two subperiods, 1996–2005 and 2006–13, clearly shows a shift in the spot price distribution; there is an increase in both spot price level and volatility. We relate these changes to the introduction of the ETS trading scheme in 2005, closer integration with the European market and a higher share of renewable energy. In the first subperiod, we find significant risk premiums during winter and fall for the majority of the futures contracts. Analyzing the second subperiod, there is evidence of a risk premium for the winter futures contracts with a holding period of one week. There is weaker evidence of a risk premium for winter and spring futures contracts with holding periods of two and three weeks.

Altogether, our findings show that risk premium is not constant. It varies across seasons (it is usually higher during the winter) as well as across time (it gradually diminishes, probably due to the market becoming more developed and efficient). This is in line with Haugom and Ullrich (2012), who find that, as the market matures, the forward prices converge toward unbiased predictors of the spot prices. Where we find evidence of biased predictions in the sample, this can be related to periods of higher prices and risk.

Possible future work would be the analysis of contracts with longer or shorter delivery periods. Other publicly known information may be added to test whether the Nordic power market is informationally efficient. An interesting continuation of this research is to model different factors describing the risk premium.

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