Understanding the Overnight Risk Premium in Forward Contracts on Electricity Traded at NASDAQ OMX and EEX

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Abstract

In this paper we conduct an empirical analysis of the overnight risk premium on electricity forward contracts traded at NASDAQ OMX Commodities and EEX. We argue that the overnight risk premium method is more relevant than the frequently used ex post method. The derivatives in this market can be divided into two classes; trading products and hedging products. Each contract shows a clear increase in trading volume and liquidity when approaching the delivery period. Incorporating this in a regression model we find that there are higher risk premiums in the period before the forward becomes a front product compared to the risk premiums in the front period. Quarterly and monthly contracts show the most significant results. In the Nordic market and the German/Austrian market this trend was more significant before 2010.

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1 Introduction

With this paper we investigate an alternative approach to analyzing the risk premium in forward contracts on electricity.[1] Using a linear regression model, we find support for a decreasing risk premium as the contract approaches maturity, varying historically, geographically and with contract lengths. We focus our attention on the Nordic and the German/Austrian power markets. We argue that the relevant market risk that the market participant takes on while holding a contract is the risk of a lower than expected realized spot price the first day of the delivery period. The delivery period is the time interval for which the agreed amount of electricity is delivered over. Moreover, we argue that there is a liquidity premium due to the low trading volume before the contract goes into front. We define the front contract as the contract with nearest duration that could be purchased in the market.

In our interpretation of the risk premium we build on the thought that the forward curves are forecasts of the future electricity spot prices, as discussed in **?** and **?**. Through the rest of this article we use the following definition for the price of a forward contract:

$$F_{t,T}^{D} \quad = \quad e^{-iT} \cdot E[S_{t+T}^{D}] \tag{1}$$

where

$F_{t,T}^{D}$	Price of a forward contract with duration T at day t for the delivery period D
i	Daily risk adjusted discount rate
T	Duration; time to the start of the delivery period in days
D	Delivery period of the contract
$E[S_{t+T}^{D}]$	Objective expected spot price over the delivery D period starting at day $t+T$

? summarize the two main views in calculation of the risk premium: the theory of storage and the expected risk premium model, also referred to as ex ante. The ex post risk premium model further develops the expected risk premium theory by substituting the expected spot price with the realized spot price. Due to the non-storable feature of electricity, expected spot prices are hard to predict. The preferred angle of analyzing the risk premium in recent years has typically been the ex post model. The ex post risk premium is defined as the difference between the realized average spot price of electricity over the delivery period of the forward contract and the forward price of electricity:

$$RP_{t,T,expost}^{P} \quad = \quad S_{t+T}^{P} - F_{t,T}^{P} \tag{2}$$

Our approach for calculating the risk premium at day t, $RP_{t,T}$, is based on equation (1). We let the overnight risk premium be the daily return on a long position in a given forward contract minus the risk free rate, r_f:

$$RP_{t,T}^{P} \quad = \quad ln(\frac{F_{t,T}^{P}}{F_{t-1,T+1}^{P}}) - r_f \tag{3}$$

[1] Throughout this paper we refer to forward contracts and future contracts meaning the same.

We emphasize that formula (2) and (3) give a different measure of risk. Equation (3) calculates the daily return for being long in a forward contract, while equation (2) calculates the pay-off for being long a forward contract. A positive pay-off, in this case for the buyer, arises when the price of the forward contract is lower than the average realized spot price. Using our approach, the return is positive if the price of the forward contract is lower at the time of purchase than when you sell it.

To understand the motivation behind the overnight risk premium approach, it is important to first define what we believe is the relevant risk in the electricity forward market. The following example illustrates our thoughts. A trader being long a forward contract with delivery period over the first quarter will have the opportunity to mitigate most of her exposure before the start of the delivery period. By a simple no-arbitrage condition, the price of the quarterly contract, $F_{Q1,t}$, must equal the sum of the price of the monthly contracts with delivery in January, February and March. The trader can simply short the February and March contracts to adjust her exposure. Further, weekly contracts can be used to hedge most of the January exposure, whereas daily contracts allow the trader to hedge for the rest of the delivery period except for the first day. Consequently, we argue that the risk the trader is compensated for when being long a forward contract, is the price risk over this day.

? never applied their model to the electricity market, but this is later done by **?**. The ex post method is the approach followed by amongst others **?**, **?**, **?** and **?**. **?**, **?** also use this method, in addition to the ex ante method. **?** regress the log return of the ex post pay-off with respect to explanatory variables. Our approach is similar to his but differs in how we calculate the return variable, as we account for hedging. An additional method of analyzing the risk premium is the two-factor Schwartz and Smith model. However, **?** argue that this model is not suitable.

The ex post method does not incorporate the traders' ability to hedge, as the overnight risk premium approach. Further, by substituting the expected spot price with the realized spot price we get the problem of separating the risk premium from the forecasting error of the market, discussed by **?**. Eliminating these errors requires long time series. Although one can argue that the forecasting error is minimal on average, it complicates the interpretation of the results. We therefore believe that our approach could be interesting research. To the best of our knowledge no recent literature has considered the overnight risk premium method in the electricity market. Our main contribution is therefore to increase the understanding of the electricity risk premium.

We believe that the risk premium depends on supply and demand for hedging and speculation, which in turn is determined by the characteristics of the market participants. Hence, to understand the magnitude of the risk premium, we look at the different market participants and their risk preferences as well as the number of outstanding contracts in the market. Depending on the different market participants they attract, we say that the derivatives in this market can be divided into two classes; trading products and hedging products. Due to highly volatile electricity prices and the unique non-storable nature of electricity, producers of power will typically want to hedge their physical production a few years ahead (**?**). When a new contract is introduced, there are no outstanding contracts in the market. Thus when producers provide contracts to the market, the traders' positions become net long. To hold this position the traders will require a risk premium, which remains positive as long as there is a positive amount of outstanding contracts available. Comparatively, in the stock market, there is a fixed amount of stocks available.

Once the contracts become front products, retailers, also subject to volatile prices as well as pervasive price spikes exhibited by electricity prices, will want to hedge their physical delivery commitments. Liquidity will also be provided by traders that are aware of this fact. Consequently, the number of outstanding contracts will be reduced, and the risk premium decreases until it disappears. An implication of this insight is that right before maturity, when the number of outstanding contracts supplied by the producers is less than the number of contracts demanded by the retailers, the negative number of outstanding contracts allows the trader to require a risk premium for being net short, and the risk premium becomes negative. In this context the trader is compensated for bearing the price risk of the producers until the retailers are willing to offset their position. This interpretation of the risk premium, as a result of the supply and demand in the forward market, is in line with **?**, **?** and **?**. **?**, **?**, **?**, **?** and **?** find negative risk premiums on average for several contract types in the Nordic market.

An implication of our interpretation is that the risk premium can be interpreted as a liquidity premium. This liquidity premium appears because of the low trading volume prior to the front period. Figure 1 shows the variations in log returns and trading volumes of the Q2-07 contracts on NASDAQ OMX and EEX respectively. The vertical lines are drawn at the day the contracts become the front contracts, i.e. become the trading products. At this point, liquidity is provided by traders and retailers, and we can clearly see the increase in trading volume for both contracts.

The remainder of this paper is organized as follows. In section 2 we describe the NASDAQ OMX and European Energy Exchange forward market. In section 3 we present our regression model. In section 4 we explain the data sets we have included in our analysis. In section 5 we present and discuss the results, while we in section 6 summarize the results and make concluding remarks.

2 Market

The Nordic electricity market is divided into a physical market, Nord Pool, and a financial market taking place at NASDAQ OMX Commodities Europe. Nord Pool is the world's first and largest multinational exchange for trade in power, and covers Norway, Sweden, Finland and Denmark. NASDAQ OMX is an exchange for trade in derivatives used for price hedging and risk management. The forward contracts traded at NASDAQ OMX are peak load and base load contracts on a specific power volume with daily-, weekly-, monthly-, quarterly- and annual delivery. The yearly base load contracts enter the market 5 years ahead of delivery, monthly contracts 6 months ahead, weekly contracts 5 weeks ahead and daily contracts 5 days ahead. The quarterly contracts

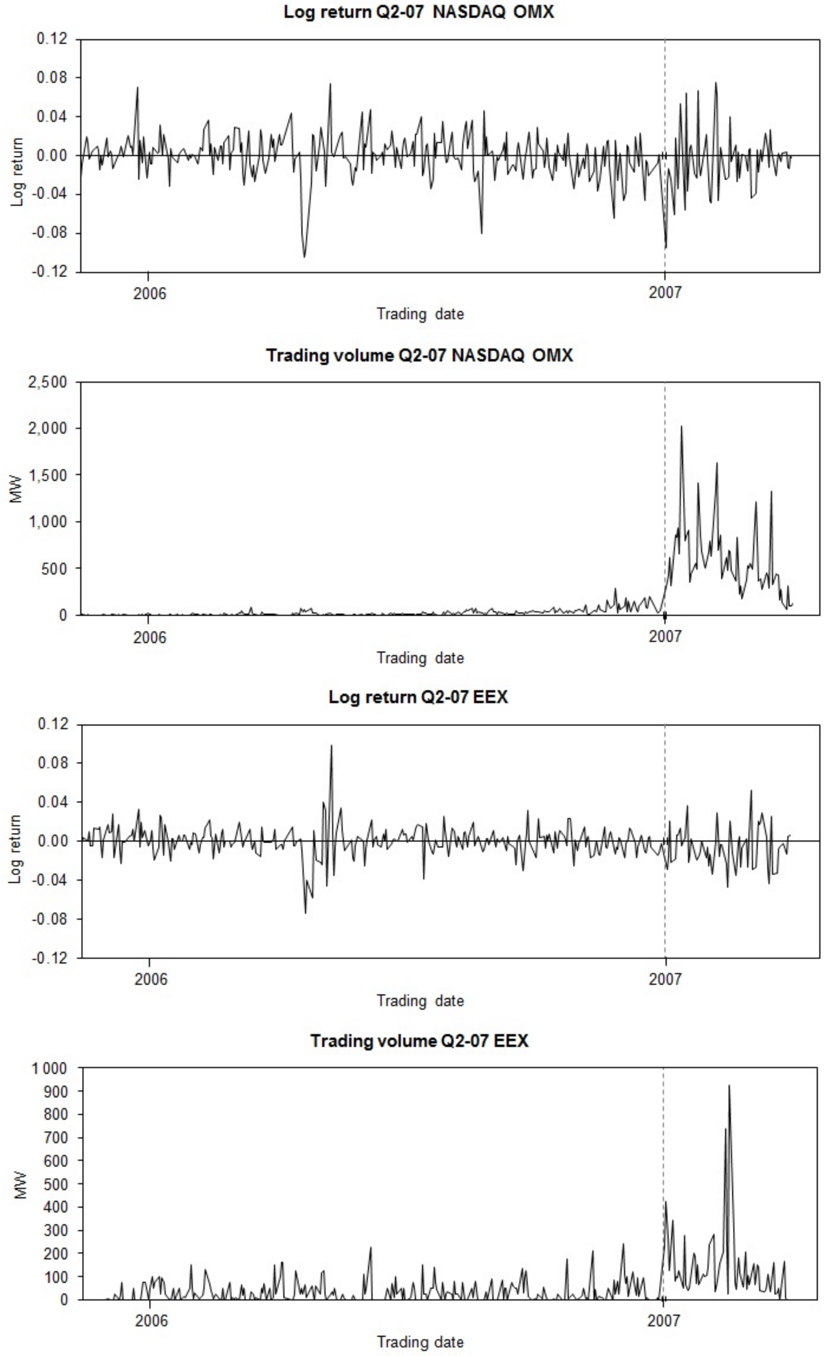

Figure 1: Log return and trading volume for the Q2-07 contracts on NASDAQ OMX and EEX

enter the market at the start of January maximum 8 quarters ahead. Further, the reference price for the financial market is the average Nord Pool Spot system price over the contract's delivery period, and the forward contracts are settled in cash with daily marking-to-market.

The European Energy Exchange, EEX, facilitates trade in financial forward contracts, named Phelix futures, which cover the market area Germany and Austria. Phelix futures are sold as base load, peak load and off-peak contracts. The delivery periods for the base load contracts are the same as in the Nordic market. The yearly base load contracts enter the market 6 years ahead of delivery, quarterly contracts 11 quarters ahead, monthly contracts 9 months ahead, weekly contracts 4 weeks ahead and daily contracts 9 days ahead. The average EPEX SPOT over the delivery period constitutes the reference price.

When entering a contract, the trader simply pays a brokerage fee. In addition she is required to have sufficient balance on a margin account. The Nordic power market has a mixture of hydro-, nuclear-, thermal- and wind power, while the German/Austrian power market has a mixture of thermal-, nuclear-, solar-, wind- and hydro power. **?** shows that the main characteristics of price formation at the EEX and Nord Pool forward markets are alike. Electricity prices in both markets are volatile and have occasional price spikes due to the non-storability of electricity, that make it difficult to dampen imbalances between supply and demand. For further details about the electricity market dynamics we refer to **?**, **?** and **?**.

3 Model

Our data analysis consists of a regression on the daily returns on the closing price from forward contracts traded at NASDAQ OMX and EEX. Our idea is that the overnight risk premium comprises the daily return on a long position in a given forward contract minus the risk free rate. Over a yearly period, the risk free rate is low and we therefore find it appropriate to assume the risk free rate to be constant and zero. This assumption will not affect our conclusion, as we are mainly interested in the development of the risk premium over the trading period. We predict that the overnight risk premium has a decreasing structure over the trading period, switching to negative when there are few contracts available in the market and retailers want to hedge their deliveries. Accordingly, we have divided the trading period in two, separated by when the contracts enter the front period. In our model we choose to incorporate this by a fixed effects dummy variable following **?**. We regress the daily returns on this front variable, to predict whether the risk premium differs in the two periods:

$$return_{f,m,t} = \alpha + \beta_1 \cdot FRO_{f,m,t} + \epsilon_{f,m,t} \tag{4}$$

where

$return_{f,m,t}$	Daily return on forward contract f in market m at time t
$FRO_{f,m,t}$	Front variable for forward contract f in market m at time t (0 before front period/1 while in front period)
$\epsilon_{f,m,t}$	Error term for forward contract f in market m at time t

The resulting α and β coefficients can be interpreted as return components. By fixing the dummy variable to its respective values we can calculate the daily returns in the two periods. The returns are annualized by using a compounding formula, assuming 250 trading days a year:

$$return_{f,m,t} = \begin{cases} e^{(\alpha)\cdot 250} - 1 & FRO_{f,m,t} = 0 \\ e^{(\alpha+\beta_1)\cdot 250} - 1 & FRO_{f,m,t} = 1 \end{cases} \tag{5}$$

The regression is repeated with the input data varying with respect to a selection of trading dates, contract types and trading areas. We expect the size of the risk premium to be time-varying as market conditions are not constant. Therefore, the analysis is extended by investigating the returns over four-year time-periods. We have chosen a four-year time-period as it includes at least a few yearly contracts. We believe, by rolling over these time-periods for each year we are still able to capture time-dependencies even though it spans a relative long time period. Concurrently, we include different sets of contract types with respect to the length of the delivery period. To test whether there are differences across markets we perform the same variety of regressions on EEX data as we do on data from NASDAQ OMX.

We later expand equation (1) with several control variables to test for robustness in our model. We highlight that our purpose with this robustness check is to test whether the effect evidenced by the dummy variable in equation (1) is still present when including variables that potentially offer alternative explanations regarding risk premia. For example **?** argue that the forward electricity risk premia conventionally regarded as the market price of risk in electricity is actually that of its underlying fuel commodity, gas. A correlation test between the control variables did not show noteworthy correlations and we therefore find it appropriate to include such a high number of variables. To account for seasonal effects we have added dummy's for each month inspired by **?** and **?**. Still, we do not expect largely observable seasonal patterns in the market price of risk, following (**?**). To avoid perfect multicollinearity, we have subsequently taken the alpha out of the regression. The expanded regression formula is thereby:

$$\begin{aligned} return_{f,m,t} =& \beta_1 \cdot FRO_{f,m,t} + \beta_2 \cdot GAS_t + \beta_3 \cdot OIL_t + \beta_4 \cdot COAL_t \\ &+ \beta_5 \cdot EMI_t + \beta_6 \cdot RES_t + \beta_7 \cdot WAV_t + \beta_8 \cdot STOCK_{m,t} \\ &+ \beta_9 \cdot VOL_{f,m,t} + \beta_{10} \cdot VAR_{m,t} + \beta_{11} \cdot SKEW_{m,t} \\ &+ \sum_{i=1}^{12} (\beta_{11+i} \cdot MONTH_{i,f,m,t}) + \epsilon_{f,m,t} \end{aligned} \tag{6}$$

where

GAS_t	Return on gas price at time t
OIL_t	Return on gas oil price at time t
$COAL_t$	Return on coal price at time t
EMI_t	Return on emission rights at time t
RES_t	Change in deviation from normal reservoir level at time t
WAV_t	Return on water value at time t
$STOCK_{m,t}$	Stock return in market m at time t
$VOL_{f,m,t}$	Change in trading volume for forward contract f in market m at time t
$VAR_{m,t}$	Spot price variance in market m at time t
$SKEW_{m,t}$	Spot price skewness in market m at time t
$MONTH_{i,f,m,t}$	Seasonal variation in month i for forward contract f in market m at time t

4 Data

Our main dataset consists of daily returns spanning the whole trading period on forward contracts. We pool the returns from all the relevant contracts.[2] The contracts involve the delivery of base load power in the Nordic area and are sold at NASDAQ OMX. As a further development of the analysis we have included corresponding contracts for Phelix futures. They are governing the German and Austrian area and sold at EEX. The forward contracts involve, as before, delivery of base load power. Data from both NASDAQ OMX and EEX is downloaded from Montel. All returns are calculated on the basis of daily closing prices as continuously compounded returns, taking the logarithm of the price at day t divided by the price at day $t-1$. We have included the mentioned contract types with delivery starting from January 2006 and ending with YR-12, Q4-12, OCT-12. This gives us 7 yearly contracts, 28 quarterly contracts and 82 monthly contracts in both markets. In all, we have 33,108 observations from NASDAQ OMX and 32,897 observations from EEX. The observation dates are in the range from 2nd January 2003 through 30th September 2012.

To distinct between the front period and the foregoing period in the analysis, we have created a dummy variable. The dummy variable is set to 1 when the contract is trading in the front period. Conversely, the dummy is set to 0 when the contract is trading before the front period.[3] Descriptive statistics of the contracts are displayed in Table 1. There we have separated the data according to this dummy variable, to get an indication of whether there are differences between the periods.

We have expanded our regression with data series for gas oil, coal, natural gas, emission rights, stock returns, reservoir level, trading volume and skewness and variance

[2]This gives us an array comprising all the returns, firstly sorted by contract type, then delivery period and chronologically by date.

[3]Monthly Phelix futures are still traded after entering the delivery period. For comparability to the NASDAQ OMX market, we have chosen to omit all trades while in the delivery period.

NASDAQ OMX Contracts

Contract types			Count		Mean, %		Median, %		Max,%		Min, %		Std dev, %		Skewness		Kurtosis	
			B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F
Y	Q	M	27879	5229	0.01	-0.08	0.05	0.00	14.09	12.74	-15.97	-16.71	1.95	2.63	-0.32	-0.17	5.25	3.00
Y	Q		19379	3514	0.03	-0.03	0.07	0.00	12.73	10.47	-15.20	-15.65	1.60	2.29	-0.48	-0.28	5.85	3.06
	Q	M	23374	3473	0.00	-0.14	0.05	-0.12	14.09	12.74	-15.97	-16.71	2.07	2.97	-0.29	-0.10	4.57	2.17
Y			4505	1756	0.03	0.02	0.04	0.10	7.74	9.19	-8.97	-9.63	1.16	1.80	-0.62	-0.40	7.95	3.39
	Q		14874	1758	0.03	-0.09	0.09	-0.05	12.73	10.47	-15.20	-15.65	1.71	2.69	-0.46	-0.19	5.12	2.07
		M	8500	1715	-0.06	-0.18	0.00	-0.20	14.09	12.74	-15.97	-16.71	2.57	3.23	-0.14	-0.03	2.90	1.99

EEX Contracts

Contract types			Count		Mean, %		Median, %		Max,%		Min, %		Std dev, %		Skewness		Kurtosis	
			B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F
Y	Q	M	27665	5232	-0.01	-0.08	0.00	-0.08	14.89	16.27	-22.52	-14.61	1.27	1.66	-0.22	0.10	12.66	8.83
Y	Q		18528	3501	0.02	-0.03	0.00	-0.04	10.91	14.63	-22.52	-8.36	1.13	1.33	-0.38	0.29	15.66	7.71
	Q	M	20921	3458	-0.02	-0.13	0.00	-0.14	14.89	16.27	-22.52	-14.61	1.39	1.86	-0.22	0.15	11.08	7.78
Y			6744	1774	0.04	0.01	0.00	0.00	7.32	8.84	-7.15	-7.05	0.82	1.19	0.11	-0.02	12.45	5.42
	Q		11784	1727	0.00	-0.07	0.00	-0.10	10.91	14.63	-22.52	-8.36	1.27	1.45	-0.42	0.49	13.73	8.26
		M	9137	1731	-0.06	-0.20	-0.04	-0.18	14.89	16.27	-19.06	-14.61	1.53	2.19	-0.04	0.09	8.73	6.03

Table 1: Descriptive statistics for return on forward contracts traded on NASDAQ OMX and EEX. B/F indicate trading before front period (B) and in front period (F).

in spot price. All of the control variables range for the period January 2003 until October 2012, unless otherwise mentioned. For each future contract, the dates in the time series are matched with the trading dates. Concurrently, we extract a time series with a time period corresponding to the selling period of the forward contract. We therefore have an equal number of time series for each control variable as we have for forward contracts, 117. Gas oil is taken as daily returns on the 1st position Gas Oil Futures traded at ICE from the Reuters EcoWin Pro database. Coal is taken as the daily returns on the 1st position in a monthly rollover series, API2 Atlantic Basin CIF, provided by Statoil. Natural gas is taken as daily returns on the ICE Natural Gas Index, from Reuters EcoWin Pro. Emission rights are taken as the 1st position in a yearly rollover series, the European Union Allowances Carbon Dioxide Yearly Rollover Series Argus Mid, provided by Statoil. The emission rights have only been traded in the market since 2005, consequently this time series is limiting the regression's time span. As a proxy for income we have used stock returns from the OMXS30 index for the Nordic area and the DAX30 index for the German and Austrian area, both from Reuters EcoWin Pro. For the reservoir level we calculated the daily difference between average reservoir level and the historical reservoir level, from Reuters EcoWin. Both the average and historical daily numbers were linearly interpolated from weekly numbers, using 7 days a week. Trading volume for each future contract are extracted from Montel. Skewness and variance are calculated using a 90 days historical rolling window on the Nord Pool system spot price for the Nordic area and the Phelix system spot price for the German/Austrian area. This is an approximation to the skewness and variance variables introduced by **?** which calculates the variable on the deviation from expected spot price.

In addition, we have created fixed effects dummy variables for all twelve months based on the trading dates for each forward contract. For example, for the MONTH_1 variable the dummy is set to 1 when the price observation in the corresponding future contract is dated in January.

5 Results

5.1 Empirical Results

Our results support our hypothesis of a decreasing risk premium as delivery approaches. The beta coefficients in our results are mostly negative, indicating lower returns on the contracts in the front period compared to the period before front. However, not all of the estimated betas are statistically significant. The results show that the risk premium for yearly contracts has a different structure compared to the quarterly and the monthly contracts and that the hypothesis was more supported before 2010. Table 2 and 3 show the results for the Nordic market and the German/Austrian market respectively. The first two columns show the time period over which the regressions have been run, while the third column shows which contract types are included in the regression.

The first six regressions are performed on different combinations of contracts spanning the whole data period. In the Nordic market, the four pooled regressions that include the quarterly contracts have statistically significant betas at a 5 % confidence level. The beta for the monthly contracts is not significant, but when the monthly contracts are pooled with the quarterly contracts, it becomes significant. The beta of the yearly contracts is not significant, and when the yearly contracts are pooled with the quarterly contracts the beta is far less significant than for quarterly contracts alone.

After the first six regressions we have extended the analysis by investigating the returns over a four-year rolling time-window. In most of the regressions that include quarterly contracts (quarterly contracts alone, quarterly contracts plus monthly contracts, and quarterly contracts plus monthly- and yearly contracts) the return in the period before front is positive and the return in the front period is negative. Moreover, the regressions that show a negative return in the period before front show an even more negative return in the front period. All of the regressions on monthly contracts alone show negative returns in the period before front, but with subsequently more negative returns in the front period. The yearly contracts are the only contracts that break the trend of negative betas. From the results we can infer that the yearly contract has a different risk premium structure compared to the quarterly and the monthly contracts. Since the beta of the yearly contracts is not significant, and when pooled with quarterly contracts the beta is far less significant than for quarterly contracts alone, we have chosen not to display the yearly plus quarterly results as it gives no further knowledge. Additionally, it is evident that the betas for earlier time intervals are the most significant, and that the trends discussed are more significant before 2010. We believe there could be a structural break caused by the financial crisis, which is present through the volatility cluster in 2008 and 2009. An alternative explanation is that the market may have become more efficient.

The results for the German/Austrian market are similar to the Nordic market. The most prominent difference is the betas of the monthly contracts, which are far more significant in the German/Austrian market. This result is evident both for the monthly contracts alone and when they are pooled with quarterly contracts. It looks as if the trend is driven by the monthly contracts in the German/Austrian market, whereas in the

Nordic market the trend seems to be driven by the quarterly contracts. Furthermore, the betas in the German/Austrian market are more significant overall.

5.2 Robustness Test with Control Variables

By adding the control variables to the regression model as in formula (6) for the Nordic market, we obtain the results presented in Table 4. The results further strengthen our hypothesis. The beta coefficient of the front dummy is still negative and statistically significant and the beta coefficients of the control variables are in most cases logically explainable. The beta for the stock return is positive and significant, indicating that the greater the stock return, the greater the return on the forward contracts.

The beta of the reservoir level variable is negative and significant. This indicates that the risk premium increases with an increase in the negative deviation from the mean level and with a decrease in the positive deviation from the mean level. The 12 betas representing seasonal variations on a monthly basis have different signs and statistical significance levels. The beta for the change in trading volume is positive with a low significance level. The positive beta indicates that an increase in trading volume is coherent with a higher return on the forward contracts. The beta for the return on water value is negative and significant, indicating that negative returns on water value are consistent with higher returns on the forward contracts. When the water value decreases, producers are more interested in hedging their income. Thereby, the risk premium increases. The beta coefficients for oil, coal and natural gas are all positive and significant. Increasing fossil fuel prices will lead to an increase in electricity prices through increased marginal production cost, which in turn will lead to an increased demand for electricity forward contracts. The beta coefficient for emission rights is also positive, but slightly less significant. For the same reason as the fossil fuels, an increase in the demand for emission rights is consistent with an increased demand for electricity forward contracts. Lastly, the betas for the skew and variance of the spot price are positive and negative respectively, both highly significant. It is worth mentioning that this is consistent with the findings of **?** even though our calculation method is slightly different. The results indicate that the greater the skew of the spot price, the greater the return on the electricity forward contracts. The negative beta coefficient of the spot price variance indicates that the higher the spot price variance, the lower the return on the electricity forward contracts.

By adding the control variables for the German/Austrian market, we obtain the results presented in Table 5. Due to lack of available data we had to omit the variables for change in trading volume, reservoir level and water value in the regression for the German/Austrian market. Hydro power is less dominant in the German/Austrian market, but the NorNed cable integrates the Nordic and the European markets and could lead to transferring of properties. It could therefore have been interesting to test these variables across both markets.

The results in Table 5 are mostly consistent with the Nordic market. The front variable is significant at a 0.1 % confidence level, compared to a 1 % confidence level in the Nordic market which indicates an even stronger structural change. The spot price variance is only significant at a 10 % confidence level, but it has the same sign as the coefficient in the Nordic market.

5.3 Discussion

Comparing the two markets we see that the yearly plus quarterly and monthly contracts pooled show a higher risk premium before front and a more negative risk premium in the front period in the Nordic market. This is also apparent for the yearly and quarterly contracts pooled, as well as for the quarterly contracts alone. In the first six regressions, performed on different combinations of contracts spanning the whole testing period, all of the results, except for those of the yearly contracts, show a more negative risk premium in the Nordic market. There are several possible explanations for this deviation between the risk premiums in the two markets. The instability of the reservoir level and the seasonal variations in precipitation in the Nordic market can create occasional price spikes and more volatile electricity prices, which in turn could give increased demand for electricity forward contracts and thus higher risk premiums. An alternative explanation could be that the lower risk premiums in the German/Austrian market are caused by a more efficient market, led by a larger amount of power producers and other market participants.

The different contract types in our regression are subject to different market circumstances. For instance, the yearly contracts have a longer duration than the quarterly and monthly contracts, there are fewer yearly contracts available over a given time horizon, and also the different contract types attract different market participants. These circumstances may explain some of the dissimilarities in the results of the different contract types.

A possible source of error in our results is the four-year rolling time-window which we have chosen to analyze the risk premium over. A shorter time horizon could possibly reveal other market conditions, and give more detailed results. However, a shorter time horizon means fewer data points to rely our conclusion on. Also, our four-year rolling time-window is time specific, not contract specific, meaning that the regression does not include the full time series of all the investigated contracts. Our results may have been different if we had considered a contract specific time horizon.

For a more accurate result, we could have incorporated the risk free rate instead of setting it to zero. However, since our goal has been to uncover the relationship between the risk premium before the front period, and the risk premium in the front period, we argue that the risk free rate is irrelevant for our investigation. Additionally, it is also questionable whether one should consider the risk free rate when there is practically no investment cost when entering a contract.

It is worth mentioning that as a parallel experiment we have conducted the same regressions as in equation (6) while simply substituting the front dummy with the daily trading volumes of the contracts in level form. This experiment also confirmed our hypothesis, conducting a statistically significant negative beta for the volume variable, which shows that high volumes (i.e. in the front period) are consistent with lower risk premiums. With the front dummy and the volume on level form showing such similar characteristics, it is natural to assume that the dummy variable catches most of the volume effect on the risk premium already. One may therefore discuss whether or not it is correct to include the volume on return form in the regression together with the front dummy. Nevertheless, the change in volume shows relatively low statistically significance, and most importantly has little or no effect on the magnitude and the statistically significance of the beta coefficient of the front variable when included in the regression.

While **?** used skew and variance variables calculated on the deviation of the realized daily spot prices from the daily expected spot prices, we have taken a simpler approach by calculating the variables directly from the spot prices. Hence, even though it appears we have the same result, it may not be appropriate to compare them. Further, **?** claim that **?** findings are only applicable before the supply shock that hit the market around the year of 2002.

While using the change in the deviation from the mean reservoir level we make no distinction between negative and positive deviations from the mean. **?** used a variable for unusual reservoir levels, and split it in two; one measuring the below-average level, and one the above-average level. Their results show that the time-varying risk premiums are significantly related to unexpectedly low reservoir levels while the abnormally high reservoir level does not have an influence on the premium.

We added the seasonal variables without expecting that they would account for the seasonal effects on the risk premium. Nevertheless, they were added to confirm robustness in the result. **?** found that the significance and size of the risk premiums in the Nordic market varied seasonally over the year; greatest during winter, and zero during summer. Our results are not consistent nor statistically significant enough for us to draw the same conclusion. A possible explanation for this is that the seasonal effects on the risk premium may already be accounted for by one or more of the other control variables, such as the variable for water values or the variable for the deviation from the mean reservoir level. This is also consistent with the fact that the beta for the month March changes sign and statistically significance level depending on the other variables included in the regression.

From the tables we see that not all of the explanatory variables are significant and some of them should have been left out using a general-to-specific method following **?** using an F-test. We have chosen to include them even though for research purposes, to show that the beta value of the front variable is still negative and statistically significant. At the same time we want to highlight that one should be careful to draw statistical inferences from our results. The residuals are found to be not normal, and we therefore have to be careful when referring to tests that assume normality.

To test for normality in the returns we used a Jarque Bera test. The test rejected the hypothesis of normally distributed residuals, which could perhaps be expected from the low R^2. If the residuals are not normally distributed, the dependent variable, or at least one of the explanatory variables, may have the wrong functional form and this makes inference more difficult. Correcting one or more of these variables may produce residuals that are normally distributed. To address this, we could adjust the returns to unit volatility through applying GARCH-models. As we would have to fit a GARCH-model for each individual forward contract, we leave this for future research.

Start date	End date	Contract types			Ann. return b/f front, %	Ann. return front, %	α	β	Pr(> |t|) α	Pr(> |t|) β	$R^2 \cdot 10^3$
01.01.2003	30.09.2012	Y	Q	M	1.3	-18.7	0.00005	-0.00088	0.6725	0.0048 **	0.2400
01.01.2003	30.09.2012	Y	Q		8.5	-8.0	0.00033	-0.00066	0.0084 **	0.0368 *	0.1904
01.01.2003	30.09.2012		Q	M	-6.0	-28.4	-0.00025	-0.00109	0.0148 *	0.0000 ***	0.6756
01.01.2003	30.09.2012	Y			7.2	5.7	0.00028	-0.00006	0.1720	0.8790	0.0037
01.01.2003	30.09.2012		Q		8.9	-19.9	0.00034	-0.00123	0.0237 *	0.0082 **	0.4205
01.01.2003	30.09.2012			M	-13.4	-36.9	-0.00057	-0.00127	0.0499 *	0.0751 .	0.3101
01.01.2003	31.12.2006	Y	Q	M	17.3	-6.1	0.00064	-0.00089	0.0009 ***	0.1246	0.2401
01.01.2004	31.12.2007	Y	Q	M	12.8	-14.0	0.00048	-0.00109	0.0023 **	0.0151 *	0.4022
01.01.2005	31.12.2008	Y	Q	M	1.0	-24.0	0.00004	-0.00114	0.8180	0.0110 *	0.3571
01.01.2006	31.12.2009	Y	Q	M	-3.0	-22.3	-0.00012	-0.00089	0.4908	0.0455 *	0.2056
01.01.2007	31.12.2010	Y	Q	M	2.3	-3.8	0.00009	-0.00025	0.5990	0.5700	0.0170
01.01.2008	31.12.2011	Y	Q	M	-5.6	-17.1	-0.00023	-0.00052	0.2310	0.2520	0.0774
01.01.2009	30.09.2012	Y	Q	M	1.1	-13.1	0.00004	-0.00061	0.8340	0.1900	0.1293
01.01.2003	31.12.2006		Q	M	18.2	-22.3	0.00067	-0.00168	0.0056 **	0.0496 *	0.5276
01.01.2004	31.12.2007		Q	M	11.9	-31.0	0.00045	-0.00193	0.0216 *	0.0021 **	0.8475
01.01.2005	31.12.2008		Q	M	-0.3	-38.4	-0.00001	-0.00193	0.9518	0.0015 **	0.7139
01.01.2006	31.12.2009		Q	M	-4.3	-31.4	-0.00018	-0.00133	0.3945	0.0204 *	0.3483
01.01.2007	31.12.2010		Q	M	2.4	-10.0	0.00009	-0.00052	0.6350	0.3530	0.0559
01.01.2008	31.12.2011		Q	M	-5.3	-23.5	-0.00022	-0.00085	0.2990	0.1300	0.1581
01.01.2009	30.09.2012		Q	M	0.4	-19.6	0.00002	-0.00089	0.9420	0.1050	0.2223
01.01.2003	31.12.2006	Y			14.3	17.0	0.00054	0.00009	0.0347 *	0.8708	0.0105
01.01.2004	31.12.2007	Y			16.1	18.0	0.00060	0.00007	0.0030 **	0.8800	0.0065
01.01.2005	31.12.2008	Y			6.5	5.9	0.00025	-0.00002	0.3050	0.9680	0.0004
01.01.2006	31.12.2009	Y			3.3	-0.3	0.00013	-0.00014	0.6360	0.7960	0.0166
01.01.2007	31.12.2010	Y			1.8	9.8	0.00007	0.00030	0.8130	0.5970	0.0800
01.01.2008	31.12.2011	Y			-7.9	-2.8	-0.00033	0.00022	0.4680	0.7620	0.0368
01.01.2009	30.09.2012	Y			10.7	5.3	0.00041	-0.00020	0.5030	0.8160	0.0363
01.01.2003	31.12.2006		Q		25.9	-10.8	0.00092	-0.00138	0.0001 ***	0.1500	0.3849
01.01.2004	31.12.2007		Q		22.7	-18.4	0.00082	-0.00163	0.0000 ***	0.0200 *	0.6993
01.01.2005	31.12.2008		Q		12.3	-28.7	0.00047	-0.00182	0.0222 *	0.0075 **	0.7824
01.01.2006	31.12.2009		Q		5.4	-23.4	0.00021	-0.00127	0.3457	0.0616 .	0.3685
01.01.2007	31.12.2010		Q		5.5	-6.0	0.00021	-0.00046	0.3190	0.4860	0.0512
01.01.2008	31.12.2011		Q		-1.9	-16.4	-0.00008	-0.00064	0.7470	0.3490	0.1033
01.01.2009	30.09.2012		Q		4.6	-11.3	0.00018	-0.00066	0.4790	0.3220	0.1506
01.01.2003	31.12.2006			M	-2.3	-33.7	-0.00009	-0.00155	0.8870	0.3810	0.3979
01.01.2004	31.12.2007			M	-10.9	-42.5	-0.00046	-0.00175	0.3420	0.1590	0.5806
01.01.2005	31.12.2008			M	-21.5	-47.2	-0.00097	-0.00158	0.0318 *	0.1647	0.3923
01.01.2006	31.12.2009			M	-18.8	-38.6	-0.00083	-0.00112	0.0412 *	0.2632	0.2104
01.01.2007	31.12.2010			M	-2.7	-13.9	-0.00011	-0.00049	0.7850	0.6120	0.0431
01.01.2008	31.12.2011			M	-10.3	-30.0	-0.00043	-0.00100	0.2640	0.2920	0.1855
01.01.2009	30.09.2012			M	-4.7	-27.0	-0.00019	-0.00106	0.6050	0.2320	0.2702

Note .p<.1, *p<.05, **p<.01, ***p<.001

Table 2: Results from regression $return_{f,m,t} = \alpha + \beta \cdot FRO_{f,m,t} + \epsilon_{f,m,t}$ run on forward contracts for the Nordic area, where $FRO_{f,m,t}$ is a dummy indicating trading in front period (1) or not (0).

Start date	End date	Contract types			Ann. return b/f front, %	Ann. return front, %	α	β	Pr(> |t|) α	Pr(> |t|) β	$R^2 \cdot 10^3$
01.01.2003	30.09.2012	Y	Q	M	-0.9	-7.6	-0.00009	-0.00076	0.2613	0.0002 ****	0.4230
01.01.2003	30.09.2012	Y	Q		1.7	-2.7	0.00017	-0.00045	0.0488 *	0.0361 *	0.1993
01.01.2003	30.09.2012		Q	M	-2.4	-11.4	-0.00025	-0.00109	0.0148 *	0.0000 ***	0.6756
01.01.2003	30.09.2012	Y			4.1	1.1	0.00039	-0.00028	0.0004 ***	0.2470	0.1574
01.01.2003	30.09.2012		Q		0.4	-6.3	0.00004	-0.00072	0.7412	0.0304 *	0.3470
01.01.2003	30.09.2012			M	-5.7	-15.7	-0.00062	-0.00138	0.0004 ***	0.0015 **	16.5000
01.01.2003	31.12.2006	Y	Q	M	8.5	6.3	0.00077	-0.00018	0.0000 ***	0.6620	0.0210
01.01.2004	31.12.2007	Y	Q	M	3.1	-8.6	0.00030	-0.00126	0.0118 *	0.0002 ***	1.0570
01.01.2005	31.12.2008	Y	Q	M	6.8	-2.7	0.00063	-0.00091	0.0000 ***	0.0034 **	0.5469
01.01.2006	31.12.2009	Y	Q	M	-3.8	-11.7	-0.00040	-0.00099	0.0022 **	0.0023 **	0.5412
01.01.2007	31.12.2010	Y	Q	M	-4.9	-10.2	-0.00053	-0.00065	0.0000 ***	0.0317 *	0.2698
01.01.2008	31.12.2011	Y	Q	M	-4.1	-6.7	-0.00043	-0.00030	0.0005 ***	0.3051	0.0648
01.01.2009	30.09.2012	Y	Q	M	-5.6	-8.6	-0.00060	-0.00037	0.0000 ***	0.1800	0.1280
01.01.2003	31.12.2006		Q	M	9.9	-0.2	0.00088	-0.00090	0.0001 ***	0.2080	0.3378
01.01.2004	31.12.2007		Q	M	2.0	-17.2	0.00019	-0.00244	0.2880	0.0000 ***	2.6230
01.01.2005	31.12.2008		Q	M	6.3	-9.2	0.00058	-0.00163	0.0003 ***	0.0003 ***	1.2480
01.01.2006	31.12.2009		Q	M	-5.7	-15.8	-0.00061	-0.00139	0.0001 ***	0.0011 **	0.8285
01.01.2007	31.12.2010		Q	M	-5.9	-13.2	-0.00063	-0.00097	0.0000 ***	0.0118 *	0.4628
01.01.2008	31.12.2011		Q	M	-4.3	-8.4	-0.00046	-0.00048	0.0006 ***	0.1804	0.1303
01.01.2009	30.09.2012		Q	M	-5.7	-10.4	-0.00061	-0.00058	0.0000 ***	0.0694 .	0.2636
01.01.2003	31.12.2006	Y			7.0	14.3	0.00065	0.00057	0.0000 ***	0.1430	0.4914
01.01.2004	31.12.2007	Y			4.9	7.7	0.00046	0.00024	0.0000 ***	0.4290	0.1191
01.01.2005	31.12.2008	Y			8.1	9.7	0.00074	0.00013	0.0000 ***	0.6890	0.0317
01.01.2006	31.12.2009	Y			3.1	-1.8	0.00029	-0.00048	0.1130	0.2260	0.3392
01.01.2007	31.12.2010	Y			0.0	-3.1	0.00000	-0.00032	0.9990	0.4390	0.1766
01.01.2008	31.12.2011	Y			-1.7	-2.9	-0.00017	-0.00013	0.5930	0.7950	0.0274
01.01.2009	30.09.2012	Y			-3.7	-3.6	-0.00039	0.00001	0.3250	0.9880	0.0002
01.01.2003	31.12.2006		Q		-0.9	-7.6	-0.00009	-0.00076	0.2613	0.0002 ***	0.4230
01.01.2004	31.12.2007		Q		6.0	-4.6	0.00056	-0.00105	0.0024 **	0.0831 .	0.6168
01.01.2005	31.12.2008		Q		8.6	3.2	0.00078	-0.00047	0.0000 ***	0.3600	0.1347
01.01.2006	31.12.2009		Q		-2.3	-10.0	-0.00023	-0.00091	0.2095	0.0864 .	0.4103
01.01.2007	31.12.2010		Q		-3.6	-9.0	-0.00038	-0.00064	0.0248 *	0.1808	0.2336
01.01.2008	31.12.2011		Q		-3.0	-5.4	-0.00032	-0.00026	0.0626 .	0.5860	0.0391
01.01.2009	30.09.2012		Q		-3.4	-8.5	-0.00036	-0.00061	0.0323 *	0.1569	0.3102
01.01.2003	31.12.2006			M	6.8	-8.1	0.00063	-0.00153	0.2010	0.2560	0.8159
01.01.2004	31.12.2007			M	-4.0	-25.1	-0.00042	-0.00352	0.2535	0.0002 ***	4.4090
01.01.2005	31.12.2008			M	3.1	-17.9	0.00030	-0.00267	0.3281	0.0005 ***	2.6800
01.01.2006	31.12.2009			M	-9.7	-20.2	-0.00111	-0.00169	0.0001 ***	0.0135 *	1.0780
01.01.2007	31.12.2010			M	-8.6	-16.8	-0.00097	-0.00122	0.0001 ***	0.0490 *	0.6413
01.01.2008	31.12.2011			M	-5.9	-11.1	-0.00064	-0.00066	0.0024 **	0.2202	0.2427
01.01.2009	30.09.2012			M	-8.0	-12.1	-0.00089	-0.00055	0.0000 ***	0.2590	0.2109

Note .p<.1, *p<.05, **p<.01, ***p<.001

Table 3: Results from regression $return_{f,m,t} = \alpha + \beta \cdot FRO_{f,m,t} + \epsilon_{f,m,t}$ run on forward contracts for the German/Austrian area, where $FRO_{f,m,t}$ is a dummy indicating trading in front period (1) or not (0).

Nordic area

Variable	Start date	End date	Contract types	Coeff.	SE	t-stat	Pr(> |t|)	R^2
Front variable				-0.00093	0.00031	-2.99	0.0028 **	
Stock returns, OMXS30				0.09297	0.00747	12.44	0.0000 ***	
ΔTrading volume[1]				0.02108	0.01088	1.94	0.0527 .	
Water value				-0.00435	0.00113	-3.85	0.0001 ***	
Spot price variance[1]				-0.02228	0.00989	-2.25	0.0243 *	
Spot price skewness				0.00020	0.00008	2.41	0.0160 *	
ΔReservoir level				-0.00162	0.00058	-2.82	0.0049 **	
Return on gas oil				0.17197	0.00608	28.29	0.0000 ***	
Return on coal				0.15369	0.00651	23.60	0.0000 ***	
Return on emission				0.06475	0.00216	30.00	0.0000 ***	
Return on natural gas				0.01422	0.00327	4.35	0.0000 ***	
January	01.01.2005	28.09.2012	Y Q M	-0.00025	0.00041	-0.62	0.5350	0.1177
February				-0.00131	0.00043	-3.07	0.0022 **	
March				-0.00059	0.00040	-1.50	0.1332	
April				0.00169	0.00042	4.04	0.0001 ***	
May				0.00124	0.00043	2.91	0.0037 **	
June				0.00068	0.00043	1.59	0.1125	
July				-0.00121	0.00042	-2.86	0.0042 **	
August				0.00128	0.00041	3.11	0.0019 **	
September				-0.00126	0.00040	-3.20	0.0014 **	
October				0.00053	0.00041	1.29	0.1976	
November				-0.00170	0.00041	-4.19	0.0000 ***	
December				0.00136	0.00046	2.98	0.0029 **	

Note .p<.0.1, *p<.05, **p<.01, ***p<.001. [1] The variable is scaled by 10,000.

Table 4: Results from regression $return_{f,t} = \sum_{i=1}^{n}(\beta_i \cdot X_i) + \epsilon_t$ run on forward data for the Nordic area

German/Austrian area

Variable	Start date	End date	Contract types	Coeff.	SE	t-stat	Pr(> |t|)	R^2
Front variable				-0.00068	0.00020	-3.36	0.0008 ***	
Stock returns, DAX				0.03235	0.00546	5.93	0.0000 ***	
Spot price variance[1]				-0.00109	0.00375	-0.29	0.7702	
Spot price skewness				0.00015	0.00007	2.34	0.0192 *	
Return on gas oil				0.09621	0.00398	24.16	0.0000 ***	
Return on coal				0.12610	0.00425	29.67	0.0000 ***	
Return on emission				0.06868	0.00146	47.22	0.0000 ***	
Return on natural gas				0.01242	0.00214	5.81	0.0000 ***	
January				-0.00137	0.00029	-4.73	0.0000 ***	
February				-0.00103	0.00029	-3.59	0.0003 ***	
March	01.01.2005	28.09.2012	Y Q M	0.00014	0.00028	0.51	0.6075	0.1623
April				0.00200	0.00027	7.42	0.0000 ***	
May				-0.00012	0.00027	-0.45	0.6530	
June				0.00096	0.00026	3.61	0.0003 ***	
July				-0.00163	0.00027	-6.07	0.0000 ***	
August				0.00005	0.00028	0.19	0.8528	
September				-0.00090	0.00027	-3.35	0.0008 ***	
October				0.00065	0.00028	2.34	0.0192 *	
November				-0.00151	0.00027	-5.65	0.0000 ***	
December				0.00096	0.00030	3.17	0.0015 **	

Note .p<.0.1, *p<.05, **p<.01, ***p<.001. [1] The variable is scaled by 10,000.

Table 5: Results from regression $return_{f,t} = \sum_{i=1}^{n}(\beta_i \cdot X_i) + \epsilon_t$ run on forward data for the German/Austrian area

6 Conclusion

This paper examines the overnight risk premium on electricity forward contracts traded at NASDAQ OMX and EEX. We argue that the commonly used ex post risk premium model does not incorporate possible hedging strategies and is subject to forecasting errors. By using the overnight risk premium method, our paper adds a new perspective in the estimation of the electricity forward risk premium.

In the empirical analysis we have used data for future contracts with delivery periods from 2006 into 2012. We have conducted a panel data regression in which we distinguish the front period from the forgoing period. The future contracts show larger trading volumes throughout the front period. We explain this increased liquidity in the front period with increased participation by retailers and speculators. An implication of this insight is that the risk premium can be interpreted as a liquidity premium prior to the volume increase in the front period.

Furthermore, we find that the risk premium decreases over time as we approach the delivery period. The daily returns on future contracts traded for the Nordic electricity market show an annual return of 1.3% prior to the front period and -18.7% in the front period. The corresponding results for the German/Austrian market are -0.9% and -7.6%, respectively. We attribute this to the reduction in the number of outstanding contracts as retailers' need for hedging arises.

Quarterly contracts give the most significant result in the Nordic market, whereas monthly contracts give the most significant result in the German/Austrian market. The beta of the yearly contracts is not significant in either market. The magnitude of the gap between the return before and in front is larger in the Nordic market compared to the German/Austrian market, and we also see a higher risk premium in the Nordic market in absolute terms. This could be an indication of market inefficiency in the Nordic Power market and a lack of integration with other financial markets.

Suggestions for further research could be to conduct and compare our results with other electricity and commodity markets to see whether the overnight risk premium method is consistent. The regression model can be estimated for different time intervals and an extended set of contracts. Further, by changing the intervals represented by the front dummy, we might obtain different results. This could especially be interesting for yearly contracts due to the long length of their front period leading to larger price uncertainty.

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