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The overnight risk premium in electricity forward contracts

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Abstract

We analyze the risk premium on electricity forward contracts traded for the Nordic and German/Austrian electricity markets. We argue that finding risk premiums by analyzing overnight returns is more relevant than the frequently used ex post approach. The derivatives in these markets can be characterized as trading products and hedging products. Each contract shows a clear increase in trading volume and liquidity when approaching maturity. We link this to a testable hypothesis where financial traders are compensated for holding price risk, and where the sign and magnitude of the risk premium changes depending on the hedging pattern of producers and retailers. Incorporating this in regressions we find that there are higher risk premiums in the period before the forwards become front products, compared to the risk premiums in the front period. Quarterly and monthly contracts show the most significant results.

1. Introduction

We analyze the risk premium in electricity forward markets, specifically the Nordic and German/Austrian market. The risk premium formation in these markets has attracted much attention in the academic community, and much of the focus has been on the ex post risk premium. The ex post risk premium is the difference between the settlement price of the forward contract and the realized average spot price over the corresponding settlement period. The ex post risk premium is investigated in Geman and Vasicek (2001), Shawky et al. (2003), Longstaff and Wang (2004), Redl et al. (2009), Bunn and Chen (2013), Veka (2013), Cartea and Villaplana (2014) and Haugom et al. (2014) amongst others. Botterud et al. (2010) regress the log return of the ex post payoff with respect to explanatory variables following Fama and French (1987). We investigate the risk premium by analyzing the forward contracts directly. Let the price of a forward contract be denoted

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by F, and the volatility of the forward contract σ. Then a simple model for the dynamics of the forward contract is

$$\frac{dF}{F} = \mu dt + \sigma dW. \tag{1}$$

A forward contract does not require an investment.[1] Since there is no investment, the forward contract should under normal circumstances not command a risk premium, hence μ in eq. (1) should be zero. However, the electricity market is different from many other markets since storing electricity is very costly. In fact, the cost of carry argument used to derive forward prices in other markets does not hold for electricity derivatives.

We distinguish between three types of players; producers, retailers and traders. 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 (Sanda et al., 2013). If there are no natural buyers in the marketplace, such as retail companies, a financial trader may be the counterpart of the producer. To take on the price risk, the trader may command a risk premium from the producer. That is, to be long in the market, the trader will require a positive risk premium and $\mu > 0$ in eq. (1). Retailers may want to hedge their physical delivery commitments. However, they do not enter the market before they know their sales obligations to end users. When these enter the market, their counterparts are the financial traders that offloaded the price risk from the producers. Financial traders have no incentive to hold contracts over settlement periods since they have no purchase or sales commitments in the spot market. When retailers meet the traders in the marketplace, the risk premium is likely to vanish, and $\mu = 0$ in eq. (1). Another scenario is that retailers will want to offload more of their price risk than the producers. This means that financial traders will be net short after selling to retailers. To hold this price risk the trader will again command a risk premium. In this case, the trader must be compensated for holding a short position, and $\mu < 0$ in eq. (1). Although this is a simplified model for the behavior in the market, it can be formulated as a testable hypothesis:

[1] Forward contracts do require a margin paid to the clearing house or as collateral for credit risk in bilateral agreements. The margin account typically pays the risk free interest rate. If the borrowing cost of the investor is the risk free rate, the forward contract will effectively not require an investment. While this is typically not the case, we assume that the entering the forward contract is costless for the investor. This is a standard assumption made in financial theory.

$$\frac{dF}{F} = (\mu + \alpha I)dt + \sigma dW, \quad I = \{0, 1\}. \tag{2}$$

In eq. (2), $I = 0$ before the retailers enter the market, and $I = 1$ afterwards. The interpretation is that the drift for the forward contract is equal to μ in the holding period of the traders, and $\mu + \alpha$ in the hedging period of the retailers. Hence we expect α to be negative. The risk premium in our model depends on supply and demand for hedging and speculation, which in turn is determined by the characteristics of the market participants. Note it does not depend on expected spot prices. We will measure the change in the forward price via the closing prices on consecutive trading days.

The next step is to identify when retailers enter the market. Electricity markets show interesting trading patterns. Figure 1 shows log returns and trading volume for the Q2-07 contracts on NASDAQ OMX and EEX. These are financially settled, where the payoff depends on the difference between the agreed contract price and the average system (spot) price during the second quarter of 2007. Notice the sharp increase in trading volume when the Q2-07 contract becomes the front product, i.e. the quarter product with shortest time to maturity. This sharp increase is interpreted as the entry point for retailers. The increased trading volume also has implications for any liquidity premium in the contract price. In fact, μ in eq. (1) might just as well be interpreted as a liquidity premium, and the sign of the premium is determined by the buyers and sellers in the market. Our arguments remain valid.

Redl et al. (2009) shows that the main characteristics of price formation at the EEX and Nord Pool forward markets are similar. Electricity prices in both markets are volatile and have occasional price spikes due to the non-storability of electricity, that makes it difficult to dampen imbalances between supply and demand. For further details about the electricity market dynamics we refer to Frestad et al. (2010), Benth et al. (2008) and Huisman and Kilic (2013). Linking the risk premium in the forward market to supply and demand of contracts has been done in Benth et al. (2008), Marckhoff and Wimschulte (2008) and Botterud et al. (2010). Geman and Vasicek (2001), Longstaff and Wang (2004), Weron (2008), Botterud et al. (2010) and Lucia and Torró (2011) find negative risk premiums on average. Our approach avoids the pitfalls mentioned by Weron and Zator (2014). In our model the risk premium is negative if $\mu + \alpha < 0$.

Following the intuition that financial traders command the risk premium, other interesting implications can be drawn. As the trader only will command a risk premium for risk that he or she must carry, any ex post estimate of the risk premium is hard to interpret. If a financial trader

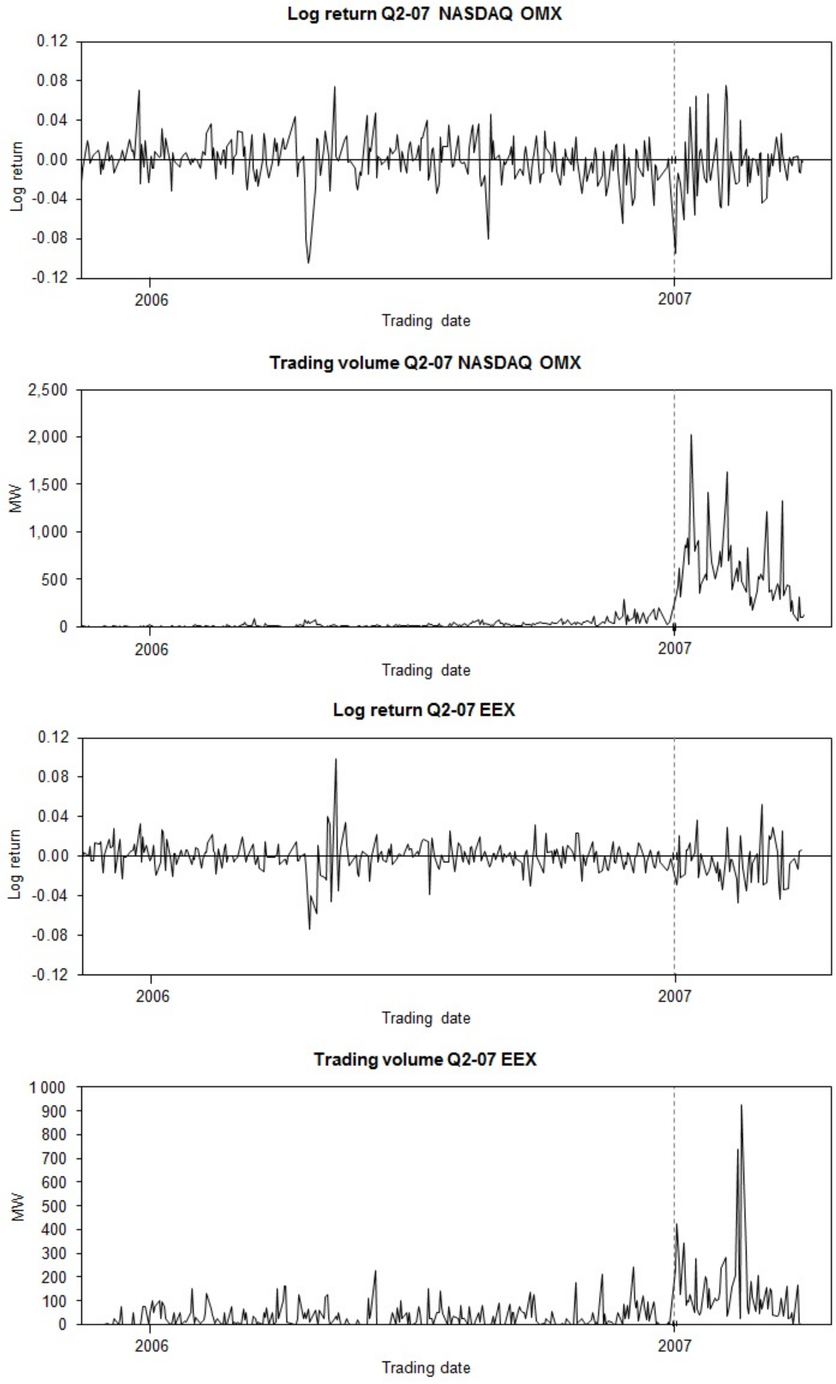

Figure 1: Log return and trading volume for the Q2-07 contracts on NASDAQ OMX and EEX. The dotted line shows when the contract becomes the front product at the exchange.

holds an annual forward contract that enters the settlement period, the ex post estimate of the risk premium will be the last closing price minus the realized spot price over the year. However, the trader does not have to hold the entire exposure throughout the year. As January approaches, the trader can simply short the remainder of the year at any day[2]. Summarizing, we hold that the underlying premise of the ex post approach is that the speculators are to buy and hold the contracts until maturity; the apparently relevant benchmark is the realized spot prices during the delivery period of the contracts. However, this kind of thinking does not match the practice of the speculators. Thus the ex post risk premium measures a compensation for risk that does not need to be held, which erodes the interpretation of such calculations.

Another problem with ex post analysis of the risk premium is well known. Using realized spot prices in the delivery period of the contracts means that there will be a forecast error component to the estimated risk premiums. Given the amount of time between the date of the relevant contract price and the realization of spot prices, the forecast error might not average to zero even over a few years, leading to uncertainty in parameter estimates. A possible approach to mitigate this problem is to analyze ex ante risk premiums using an explicit spot price model (Benth et al., 2008; Weron, 2008; Benth et al., 2013). However, the estimated risk premiums then become dependent on the subjective choice of spot price expectation, for which no consensus model exists.

Our contributions include an alternative approach to estimating risk premiums, avoiding previously unrecognized issues with interpretation of ex post analysis. We formulate a testable hypothesis that is supported by analyzing electricity forward contracts in the Nordic and EEX electricity markets, thereby shedding new light on how the risk premiums are formed.

[2]Consider another example. A trader is long a Q2 contract. At 1 April, this contract has entered its settlement (delivery) period and the trader is exposed to the difference between the contract price and the realized spot price over the remainder of Q2. However, much of the risk can be offloaded, by shorting the May and June contracts, and hold these throughout the quarter. The remaining exposure is to April spot prices, but for this the trader can short the last three weeks of April. Further, there exists day futures to cover daily exposure, meaning the remainder of the week can be hedged. The only risk the trader cannot hedge is the overnight price change. The ex post risk premium measures a compensation for carrying risk that is hedgeable, thus it loses interpretation power. This reasoning carries over to other commodities as well. It does not apply when e.g. trading day-ahead forward contracts in the US (Bessembinder and Lemmon, 2002; Longstaff and Wang, 2004; Haugom and Ullrich, 2012), since these contracts cannot be hedged.

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 indicates trading before front period (B) and in front period (F).

2. Data

We have examined prices from the Nordic market as traded at NASDAQ OMX and German/Austrian contracts traded at EEX. Our data set spans 2 January 2003 to 30 September 2012. It consists of 7 annual contracts, 28 quarterly contracts and 82 monthly contracts in both markets; 33108 observations of NASDAQ OMX prices and 32897 observations of EEX prices. Descriptive statistics of the contracts is given in Table 1.

3. Risk premium estimation

The formulation in eq. (2) must be discretizised to be fitted to observed data. The resulting model can be stated as

$$r_t \sim N((\mu + \alpha I_t)\Delta t, \sigma\sqrt{\Delta t}), \tag{3}$$

or

$$r_t = \mu + \alpha I_t + \epsilon, \tag{4}$$

where r_t is the first difference of the natural logarithm of the forward price, $\Delta t = 1$ day and $\epsilon \sim N(0, \sigma)$. It is well known that the log returns of financial series are not normally distributed. We employ ordinary least squares to estimate μ and α, thus the estimators are unbiased even without the assumption of normally distributed returns. The annualized risk premium, given daily observations of the forward curve, is given by

$$e^{(\mu+\alpha I_t)252} \tag{5}$$

for 252 trading days per year.

Redl and Bunn (2013) and Bunn and Chen (2013) argue that the forward electricity risk premium is dependent on the underlying fuel. We therefore expand the model to control for fuels, second and third moment of returns and seasonal effects as in Longstaff and Wang (2004) and Lucia and Torró (2011). The estimated model includes the following control variables;

GAS_t	Logarithmic return of ICE Natural Gas Index,
OIL_t	Logarithmic return of front line ICE gas oil futures,
$COAL_t$	Logarithmic return of front line API2 Atlantic Basin, CIF,
EMI_t	Logarithmic return of Argus European Union Allowances Carbon Dioxide front year,
RES_t	Deviation from normal Nordic hydro reservoir level,
WAV_t	Logarithmic return of Nordic water value[3],
$STOCK_t$	Logarithmic return of the stock market,
VOL_t	Change of trading volume,
VAR_t	Spot price variance,
$SKEW_t$	Spot price skewness,
$MONTH_{it}$	Seasonal variation, monthly dummies.

For both markets, the regressions are on the form

$$\begin{aligned} r_t =& \alpha_1 \cdot I_t + \alpha_2 \cdot GAS_t + \alpha_3 \cdot OIL_t + \alpha_4 \cdot COAL_t \\ &+ \alpha_5 \cdot EMI_t + \alpha_6 \cdot RES_t + \alpha_7 \cdot WAV_t + \alpha_8 \cdot STOCK_t \\ &+ \alpha_9 \cdot VOL_t + \alpha_{10} \cdot VAR_t + \alpha_{11} \cdot SKEW_t \\ &+ \sum_{i=1}^{12} (\alpha_{11+i} \cdot MONTH_{it}) + \epsilon_t, \end{aligned} \tag{6}$$

however, water value, trading volume and reservoir level was not used for the EEX.

We estimate the model for individual contracts and using pooled ordinary least squares to

[3] As a proxy for the water value, we follow Sandsmark and Tennbakk (2010) and use the spot price in the zone NO1 in Norway, which contains only hydropower plants.

sharpen statistical inference. We have fitted the model over different time periods to reveal possible changes in parameter values over time.

4. Results

Table .2 and Table .3 show the results for the Nordic market and the German/Austrian market respectively. The first two columns show the time period, while the third column shows which contract types are included in the regression.

The first six rows represent models that are estimated 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 risk premium parameters at a 5 % confidence level. The estimated risk premium for monthly and quarterly contracts gives support for our hypothesis. We do not see the same effect for annual contracts. One reason for this might be that retailers do not hedge purchases on an annual basis, but focus on shorter term contracts such as weekly, monthly or quarterly.[4]

The remaining rows contain results of an analysis of returns for four-year rolling time windows. In most of the regressions that include quarter contracts, the return in the period before front is positive and the return in the front period is negative. We see that our hypothesis has more support in earlier time periods, that is, before 2010. This may represent a structural break caused by the worldwide financial debt crisis. It may also be interpreted as improved market efficiency. While it is difficult to pin down the cause of the observed change, we can provide statistical evidence that a change did occur. To do so, we estimate two models for each market; one where the effect is restricted to be constant over the whole sample, and one model where we include a dummy variable that takes the value of one if the data point is observed before 1. January 2010, and zero otherwise. This allows us to test for parameter stability using an ANOVA test. Under the null hypothesis the test statistic follows an F distribution, with parameters dependent on sample size and the number of imposed restrictions. For the Nordic market the test statistic is F distributed on 28242 degrees of freedom, and takes the value of 8.20. The corresponding p-value is 0.004. The German/Austrian market parameter stability test if F distributed on 27978 degrees of freedom, and takes the value of 21.15. The corresponding p-value is 4.27e-06.

[4]Residential customers use 1-year fixed contracts to a very limited extent according to Mirza and Bergland (2012).

The German/Austrian market results offer support for our hypothesis. The effect of the front dummy on the risk premium sign and size is most prominent for monthly contracts in this market.

Robustness of the results is checked by adding the control variables to the regressions, i.e. running regressions on the form (6). The results are detailed in Appendix A. The results further strengthen our hypothesis. The coefficient of the front dummy is still negative and statistically significant, and the signs of the coefficients for the control variables are in most cases as expected.

The coefficient for the stock return is positive and significant, indicating that the greater the stock return, the greater the return on the forward contracts. The coefficient for 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 positive coefficient associated with trading volume indicates that an increase in trading volume is consistent with a higher return on the forward contracts. Return on water value has a negative and significant effect, 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 revenue. Thereby the risk premium increases. The 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 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. Finally, the coefficients 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 Bessembinder and Lemmon (2002) even though our variable definitions are 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 coefficient of the spot price variance indicates that the higher the spot price variance, the lower the return on the electricity forward contracts.

As an additional control, we have run the same regressions as in eq. (6) except substituting the front dummy with the daily trading volumes of the contracts in level form. This experiment also confirm our hypothesis, giving a statistically significant negative coefficient for the volume variable, which shows that high volumes (i.e. in the front period) are consistent with lower risk premiums.

5. Conclusion

This paper examines the risk premium on electricity forward contracts traded at NASDAQ OMX and EEX. We have formulated a testable hypothesis where financial traders are compensated for holding price and liquidity risk. The novelty of our approach is that we analyze overnight returns, which is more in line with the exposure that traders in these markets actually hold. We have analyzed empirical data from month, quarter and annual delivery length products, and find strong support for our hypothesis. That is, the risk premiums in the markets are positive, on average, when producers hedge their production, and turn negative when large buyers, e.g. retailers, enter the market. Front contracts, i.e. those nearest to maturity, are trading (speculative) products, while the products further out on the forward curve are hedging products.

We have used data for contracts with delivery periods from 2003–2012. 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 % when producers hedge, and -18.7 % after retailers enter the market. The corresponding results for the German/Austrian market are -0.9 % and -7.6 %, respectively. These negative risk premiums confirm previous findings.

Quarterly contracts show the most prominent effect in the Nordic market, whereas monthly contracts give the most significant result in the German/Austrian market. Annual contracts show no effect on the risk premium of market participation in either market. We find 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.

6. Acknowledgements

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Table .2: Results from regression $r_t = \mu + \alpha I_t + \epsilon_t$ (4) run for overnight return on forward contracts for the Nordic area, where I_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, %	μ	α	Pr(> |t|) μ	Pr(> |t|) α	$R^2 \cdot 10^3$
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 .3: Results from regression $r_t = \mu + \alpha I_t + \epsilon_t$ (4) run for overnight return on forward contracts for the German/Austrian area, where I_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, %	μ	α	Pr(> |t|) μ	Pr(> |t|) α	$R^2 \cdot 10^3$
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 $.p < .1$, $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Appendix A. Control regressions

The control variables are data series for gas oil, coal, natural gas, emission rights, stock returns, reservoir level, trading volume and skewness and variance in spot price. 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. The emission rights have only been traded in the market since 2005, consequently this time series is limiting the regressions time span. As a proxy for general market return 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 volumes for the future contracts 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 Bessembinder and Lemmon (2002) which calculates the variable on the deviation from expected spot price.

Nordic area

Variable	Coeff.	SE	t-stat	Pr(> |t|)
Front dummy	-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	-0.00025	0.00041	-0.62	0.5350
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 A.4: Results from regression $r_t = \sum_{i=1}^{n} (\alpha_i \cdot X_i) + \epsilon_t$ (6) run on forward data for the Nordic area. Start date is 1 January 2005, end date is 28 September 2012. All contract types (month, quarter, year) are pooled.

German/Austrian area

Variable	Coeff.	SE	t-stat	Pr(> |t|)
Front dummy	-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	0.00014	0.00028	0.51	0.6075
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 A.5: Results from regression $r_t = \sum_{i=1}^{n}(\alpha_i \cdot X_i) + \epsilon_t$ (6) run on forward data for the German/Austrian area. Start date is 1 January 2005, end date is 28 September 2012. All contract types (month, quarter, year) are pooled.

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