Market Power in the Expanding Nordic Power Market*

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Abstract

The purpose of this paper is to examine whether the common Nordic power market, Nord Pool, has been competitive or if suppliers of electric power have had market power. Specifically, because the evolution from national markets to a multi-national power market has taken place step by step, we examine how the degree of market power has evolved during this integration process. The theoretical framework is the Bresnahan [4]-Lau [15] method and the analysis is performed using weekly data for the period 1996 to 2004. The results show that suppliers of electricity have had small, but statistically significant, market power during this period, and that the degree of market power has been reduced as the Nord Pool area has expanded.

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Keywords: Bresnahan-Lau method, conjectural variation elasticity, electricity market, market power and Nord Pool.

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1 Introduction

Background The Nordic countries have cooperated during several years to provide their citizens with an efficient and reliable source of electricity. Therefore, since the beginning of the 1990s, there has been an evolution from national markets to a multi-national and largely deregulated electricity market. That is, Norway, Sweden, Finland and Denmark have all reformed their electricity sectors and have today access to a common wholesale electricity market. The Nordic electricity market consists of two parts: (i) bilateral trade of electricity contracts between operators; and (ii) the non-mandatory Nordic power exchange, Nord Pool.

Purpose of the paper Since the aim of the reforms has been to develop a competitive electricity market, which would benefit consumers, one may ask whether these efforts have been successful: is the common wholesale electricity market characterized by perfect competition or do suppliers of electricity have market power? Moreover, because the evolution from national markets to a multi-national market has taken place step by step, it would be interesting to know how the degree of market power has evolved during this integration process. This paper's purpose is to provide answers to both questions.

Measuring market power ... A natural measure of a market's competitiveness is the price-marginal cost markup since the price is equal to the marginal cost at a perfectly competitive market. Having the Nordic power exchange in mind, this means that the electricity price should equal the cost of producing the marginal unit of electricity. Otherwise, suppliers of electricity have market power.

Even though market prices are often easily accessible, this is not the case with marginal costs. An exception, however, is Wolfram's [20] study of the deregulation of the British electricity market, where marginal costs are available due to the access to detailed information on plant level efficiency, and the price-marginal cost markups show that the British electricity market is not far from being characterized by perfect competition.[1]

Unfortunately, we do not have access to information on plant level efficiency since this information is kept confidential. Consequently, we must rely on some other method to measure the degree of market power, and one such method that also forms the basis for the approach taken in this paper is conjectural variations, also named the Bresnahan [4]-Lau [15] method.

... with the Bresnahan-Lau method ... The conjectural variation elasticity at the industry level, which is the focal point in this method, can be interpreted as the average of the individual firm's conjectural variation elasticities. Specifically, the latter elasticity is a measure of all firms output response relative to a single firm's output change as conjectured by the firm. Thus, if there is perfect competition, there is no output response since a single firm cannot affect output at the industry level, whereas the response is one-to-one if there is no competition since the whole industry behaves as a single firm.

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[1] A shortcoming in Wolfram [20] is that the information on plant level efficiency is dated before the start-up of the deregulation of the British electricity market.

Having the electricity market in mind, the conjectural variation elasticity is estimated from a system of two equations, where the first equation is aggregate demand for electricity that is a function of the electricity price and at least one exogenous variable, whereas the second equation is an aggregate supply relation that is derived from profit maximization. Specifically, the supply relation is the electricity price as a function of industry output, the same exogenous variables as in aggregate demand and possibly some other exogenous variables.

The exogenous variable that appears in both equations is introduced to solve an identification problem. Bresnahan [4] solved this problem by using a rotation variable in the aggregate demand equation, whereas Lau [15] showed that the identification of market power is possible as long as aggregate demand is non-separable in at least one exogenous variable. Thus, if at least one exogenous variable is part of an interaction term in the aggregate demand equation, the identification problem is solved since the interaction term acts as a rotation variable and it is also non-separable in the exogenous variable.[2]

... in an error-correcting framework Even though the degree of market power can be identified by the Bresnahan-Lau method or model, Steen and Salvanes [18] argue that a dynamic reformulation of the model into an error-correcting framework is necessary for two reasons. The first is that this framework allows for short-run deviations from long-run equilibrium in data, and the second reason is that this framework solves the inference problem when using non-stationary data. Therefore, since we use weekly data that are non-stationary, we make use of Steen and Salvanes' [18] dynamic framework in the empirical analysis.

Earlier literature There are few empirical studies that actually measure market power in the Nord Pool area, and none of them have studied the effects of market expansion on the degree of market power. Hjalmarsson [11] and Vassilopoulos [19] look at the system price and show that the power market has been characterized by competition, while Johnsen [14] and Steen [17] focus on the Norwegian market but does not investigate the system level.

There are, however, several studies that analyze the potential for market power, both *ex ante* and *ex post* market deregulation. Amundsen and Bergman [1] analyze the effects of cross-ownership in the electricity market and how mergers will affect the electricity market. They conclude that mergers, as well as cross-ownership, may re-establish at least part of the market power that deregulation removed.

In a more recent paper, Amundsen and Bergman [2] compare the Nordic power market to the Californian power market, and find that the Nord Pool market has been working well. According to Amundsen and Bergman [2], the reasons are that the Nordic market is characterized by a simple but sound market design, successful dilution of market power, strong political support

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[2] This method has been criticized by Corts [6], who showed that the estimated conjectural variation elasticity measures the marginal, and not the average, collusive behavior in an industry. However, using direct measures of marginal costs to calculate the "true" value of the conduct parameter, Clay and Troesken [5] and Genesove and Mullin [9] have shown that the method preforms well as long as the degree of market power is not too high. Thus, since Nord Pool consists of over 100 firms, it is reasonable to believe that the Bresnahan-Lau method is appropriate to use.

for a market-based electricity supply system, and, finally, voluntary informal commitment to public service by the power industry.

Finally, Edin [7] analyze the Nord Pool area using a model suited for hydro power intensive markets, and discusses the possibility that the threat of entry into the Nordic market could explain that prices follow the marginal cost of production rather closely.

Contribution in the paper The contribution in this paper is not only an empirical examination of the degree of market power in the Nordic electricity market, but also an examination of how this degree of market power has been affected by the market expansion that has taken place when Finland and Denmark step by step have joined Norway and Sweden in the common electricity market. Thus, with a larger sample than in previous literature, these entries are incorporated into the empirical analysis.

The results show that suppliers of electricity have a small, but statistically significant, degree of market power in the Nordic electricity market during the whole period under study. In addition, the degree of market power has been reduced as the market has expanded.

Outline of the paper The Bresnahan-Lau model is presented in Section 2, Section 3 contains the empirical analysis, and Section 4 concludes the paper with a discussion.

2 The Bresnahan-Lau model

The static Bresnahan-Lau model is presented in Section 2.1, and Steen and Salvanes' [18] dynamic reformulation of the model into an error-correcting framework is presented in Section 2.2.

2.1 The static model

Basically, the Bresnahan-Lau model is a static model since there are no lagged or lead values of the variables included. Specifically, the aggregate demand function for electricity is

$$Q = D\left(P, Z; \alpha\right) + \varepsilon, \tag{1}$$

where Q is quantity demanded, P is the price of power, Z is a vector of exogenous variables, α is a vector of parameters to be estimated, and ε is a random disturbance term. If we turn to the supply side of the power market, the aggregate supply relation is

$$P = c\left(Q, W; \beta\right) - \lambda h\left(Q, Z; \alpha\right) + \eta, \tag{2}$$

where W is a vector of exogenous variables, β is a vector of parameters to be estimated, λ is a measure of the degree of market power, and η is a random disturbance term.

The function $c\left(\cdot\right)$ in (2) is the marginal cost of producing electricity, meaning that when $\lambda = 0$, the price of power is equal to the marginal cost. This case corresponds to a perfectly competitive power market since all suppliers of electricity are price-takers. However, when suppliers are price-setters, the marginal revenue as perceived by the single supplier is equal to the marginal cost, and this is because $P + h(\cdot)$ is the marginal revenue at the industry level and λ can be viewed as the perceived percentage of this revenue. Therefore, when $\lambda = 1$, we have a perfect cartel in the power market.

Obviously, the aggregate demand function and the aggregate supply relation in (1)-(2) are on general forms, but by assuming a linear demand function for electricity,

$$Q = \alpha_0 + \alpha_P P + \alpha_Z Z + \alpha_{PZ} PZ + \varepsilon, \tag{3}$$

including an interaction term between P and Z that acts as a rotation variable, and a linear marginal cost function,

$$c(\cdot) = \beta_0 + \beta_Q Q + \beta_W W, \tag{4}$$

the supply relation for electricity is

$$P = \beta_0 + \beta_Q Q + \beta_W W - \lambda \cdot \underbrace{\left(\frac{Q}{\alpha_P + \alpha_{PZ} Z} \right)}_{=Q^*} + \eta. \tag{5}$$

Thus, if we first estimate the aggregate demand function in (3), meaning that we can calculate Q^*, we can identify the degree of market power, λ, after having estimated the aggregate supply relation in (5).

2.2 The dynamic model

As already mentioned, Steen and Salvanes [18] argue that a dynamic reformulation of the Bresnahan-Lau model into an error-correcting framework is necessary for two reasons. The first is that this framework allows for short-run deviations from long-run equilibrium in data, and the second reason is that this framework solves the inference problem when using non-stationary data. Therefore, since we use weekly data that are non-stationary, we make use of Steen and Salvanes' [18] dynamic framework in the empirical analysis.

Start by writing the aggregate demand function for electricity as an autoregressive distributed lag model:

$$\begin{aligned} Q_t \quad = \quad & \alpha_{P,0} P_t + \alpha_{P,1} P_{t-1} + \alpha_{Z,0} Z_t + \alpha_{Z,1} Z_{t-1} + \\ & \alpha_{PZ,0} PZ_t + \alpha_{PZ,1} PZ_{t-1} + \alpha_{Q,1} Q_{t-1} + \varepsilon_t, \end{aligned} \tag{6}$$

and continue by also writing the aggregate supply relation for electricity as an autoregressive distributed lag model:

$$\begin{aligned} P_t \quad = \quad & \beta_{Q,0} Q_t + \beta_{Q,1} Q_{t-1} + \beta_{W,0} W_t + \beta_{W,1} W_{t-1} + \\ & \lambda_0 Q_t^* + \lambda_1 Q_{t-1}^* + \beta_{P,1} P_{t-1} + \eta_t, \end{aligned} \tag{7}$$

where the long-run stationary equilibrium is found by setting $Q_t = Q_{t-1}$, $P_t = P_{t-1}$, $Z_t = Z_{t-1}$, $PZ_t = PZ_{t-1}$, $W_t = W_{t-1}$ and $Q_t^* = Q_{t-1}^*$.

As is shown in Steen and Salvanes [18], the distributed lag models in (6)-(7) can be written in error-correcting forms. Specifically, if we relax the restriction of one lag and include an intercept term, the aggregate demand function and the aggregate supply relation are

$$\begin{aligned}\Delta Q_t &= \alpha_0 + \sum_{i=1}^{k-1} \alpha_{Q,i} \Delta Q_{t-i} + \sum_{i=0}^{k-1} \alpha_{P,i} \Delta P_{t-i} + \\ & \sum_{i=0}^{k-1} \alpha_{Z,i} \Delta Z_{t-i} + \sum_{i=0}^{k-1} \alpha_{PZ,i} \Delta PZ_{t-i} + \\ & \gamma^* \left(Q_{t-k} - \frac{\alpha_P^*}{\gamma^*} \cdot P_{t-k} - \frac{\alpha_Z^*}{\gamma^*} \cdot Z_{t-k} - \frac{\alpha_{PZ}^*}{\gamma^*} \cdot PZ_{t-k} \right) + \varepsilon_t, \end{aligned} \tag{8}$$

and

$$\begin{aligned}\Delta P_t &= \beta_0 + \sum_{i=1}^{k-1} \beta_{P,i} \Delta P_{t-i} + \sum_{i=0}^{k-1} \beta_{Q,i} \Delta Q_{t-i} + \\ & \sum_{i=0}^{k-1} \beta_{W,i} \Delta W_{t-i} + \sum_{i=0}^{k-1} \lambda_i \Delta Q_{t-i}^* + \\ & \psi^* \left(P_{t-k} - \frac{\beta_Q^*}{\psi^*} \cdot Q_{t-k} - \frac{\beta_W^*}{\psi^*} \cdot W_{t-k} - \frac{\lambda^*}{\psi^*} \cdot Q_{t-k}^* \right) + \eta_t. \end{aligned} \tag{9}$$

We refer to Steen and Salvanes [18] for explicit derivations as well as a discussion on the relationship between the distributed lag models in (6)-(7) and their error-correcting forms in (8)-(9).

Since statistical tests performed on the data set reveal that it is a mixture of stationary and non-stationary variables, an autoregressive distributed lag formulation is used for the aggregate demand function for electricity (see (6)), while an error-correcting formulation is used for the aggregate supply relation for electricity (see (9)).

3 Empirical analysis

The data set is presented in Section 3.1, statistical tests performed on the data set are found in Section 3.2, and Section 3.3 contains the estimation results.

3.1 Data set

The data set consists of weekly information from all Nord Pool participants, covering the period from week 1 in 1996 to week 16 in 2004. See Table 1 for specific dates in the integration process, and Table 2 for variables used, their definitions and data sources.

[Tables 1-2 about here.]

The price variable in focus is Nord Pool's spot price at the system level (P). Further on, since the industry sector is the largest consumer of electricity, we include industrial production (*Prod*) when studying electricity demand. A problem, however, is that data are available only on a monthly basis, whereas all other variables are available on a weekly basis. There are two options at hand: (i) to exclude this variable (see Vassilopoulos [19]); or (ii) to interpolate the data into weekly estimates (see Hjalmarsson [11]). In our opinion, industrial production is important and since the variation of this variable within each month is expected to be small, we choose to interpolate.

Two other variables affecting demand are the temperature (*Temp*), which is a proxy for the amount of electricity needed for heating, and the length of a day (*Daylength*), which is a proxy for the amount of electricity needed for lightning. Moreover, to be able to identify the degree of competition in the electricity market, we need at least one interaction variable as discussed above. Therefore, we let the spot price at the system level to interact with the temperature as well as the length of a day in the Nord Pool area (*P*Temp* and *P*Daylength*), meaning that we make use of two interaction variables in the analysis.

To determine electricity supply, we need to approximate the marginal cost function and also to find variables that shifts this function. To approximate the marginal cost function, we look at the opportunity cost of hydro generation, and two factors that affect this cost are inflow of water to reservoirs (*Inflow*) and how full they already are (see Hjalmarsson [11] and Johnsen [14]). We choose to use inflow as a shift variable for the supply relation. The Nordic power market consists of a relatively large amount of hydro generation that is a cheap electricity source and has almost no variable costs at all.[3] Hydro power is, therefore, considered as base load electricity in the Nord Pool area. Nuclear power is more expensive than hydro power, but has also fairly low variable costs and is, therefore, also considered as base load electricity.

When more energy is needed, more expensive sources such as thermal power are used.[4] In the Nord Pool area, this electricity is produced with a number of inputs such as coal, gas, oil and bio fuel. Opposite to hydro and nuclear power that have low and almost constant variable costs, the technology of residual electricity has higher and increasing variable costs (see Green and Newbery [10]). Consequently, we incorporate the coal price (*Coal*) and the Brent crude oil price (*Oil*) into the supply relation to account for the thermal part of electricity generation. Moreover, to account for the residual electricity trend, we include residual electricity in relation to total electricity production (*Resel*) as a variable in the analysis.

Finally, the increase in electricity traded at Nord Pool's spot market is an exogenous trend that need to be taken into consideration when building the empirical model.[5] Following Hjalmarsson [11], this is accomplished by regressing the system turnover (*Turnover*) on the market share (*Market share*) and use the residual as a detrended quantity variable (Q).

See Table 3 for descriptive statistics of all variables used in the empirical analysis for the different subperiods in the integration process.

[Table 3 about here.]

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[3] For example, Andersson and Bergman [3] approximate the variable costs for hydro generation with the wage costs and specify these to be 0.01 SEK/KWh.

[4] Energy additional to the base load are referred to as residual electricity.

[5] In 1996, about 16 percent of all electricity in the Nord Pool area were traded at Nord Pool's spot market, whereas in 2003, about 30 percent of all electricity were traded at the same market.

3.2 Statistical tests

Before specifying the regression model, we need to test whether the variables are stationary. If this is not the case, we also need to test for cointegration to ensure the existence of a long-run equilibrium in the data set. Finally, a separability test is preformed on the interaction variables to make sure that the degree of market power is identifiable due to Lao's [15] impossibility theorem.

Dickey-Fuller's augmented unit root test is used in companion with the AIC to test whether the variables are stationary. A potential problem, however, is that the variables are highly seasonal, meaning that we have to deseasonalize the data before using the test. This is accomplished by introducing weekly dummy variables and estimate the following equation:

$$y_t = \alpha_0 + \sum_{i=2}^{52} \alpha_i Week_i + \hat{y}_t, \tag{10}$$

where $\hat{y}_t$ is the regression residual that can be viewed as the deseasonalized value of y_t. See Table A.1 in the Appendix for results.

Thereafter, we use the Johansen [13] approach to search for cointegrated relations between the variables. Specifically, we use the Johansen and Juselius [12] multivariate cointegration test, which is a maximum likelihood test on the results from a vector autoregression. Again, a potential problem is that the variables are highly seasonal, meaning that the deseasonalized data are used in the test. See Tables A.2-A.3 in the Appendix for results, which show that we have cointegrated relationships among the integrated variables, both at the demand and supply sides of the power market.

Finally, the aggregate demand function must be non-separable in at least one of the interaction variables, and the appropriate test is an extension of the cointegration test by introducing restrictions that the interaction variables are zero. The restricted model is, thereafter, compared to the unrestricted model using a likelihood ratio test. See Table A.2 in the Appendix for results, which show that the interaction variables should be included in the regression model.

3.3 Estimation results

The aggregate demand function and the aggregate supply relation for electricity are

$$\begin{aligned} Q_{tj} \quad = \quad & \alpha_0 + \sum_{i=1}^{k} \alpha_{Q,i} Q_{t-i} + \sum_{i=0}^{k} \alpha_{Prod,i} Prod_{t-i} + \\ & \sum_{i=0}^{k} \alpha_{Temp,i} Temp_{t-i} + \sum_{i=0}^{k} \alpha_{Daylength,i} Daylength_{t-i} + \\ & \sum_{j=1}^{l} \sum_{i=0}^{k} \alpha_{CV_j,i} CV_{j,t-1} + \varepsilon_t, \end{aligned} \tag{11}$$

and

$$\begin{aligned}\triangle P_{tmj} \quad = \quad & \beta_0 + \sum_{m=1}^{q}\sum_{i=1}^{k}\beta_{P_m,i}\triangle P_{m,t-i} + \sum_{i=0}^{k}\beta_{Q,i}Q_{t-i} + \\ & \sum_{i=0}^{k}\beta_{Q^2,i}Q^2_{t-i} + \sum_{i=0}^{k}\lambda_i Q^*_{t-i} + \sum_{i=0}^{k}\beta_{Inflow,i}Inflow_{t-i} + \\ & \sum_{i=0}^{k}\beta_{Coal,i}Coal_{t-1} + \sum_{i=0}^{k}\beta_{Oil,i}Oil_{t-1} + \\ & \sum_{i=0}^{k}\beta_{Resel,i}Resel_{t-i} + \sum_{j=1}^{l}\gamma_{CV_j}CV_{t-1} + \eta_t,\end{aligned} \tag{12}$$

where $\{CV\}_{j=1}^{l}$ are cointegrated vectors in the demand function and supply relation, respectively. Because of a simultaneity problem that arises in demand and supply models, two-stage least squares (2SLS) is used in the analysis. In the aggregate demand function in (11), the first lag of the system price (P), the temperature (*Temp*), and the inflow of water to reservoirs (*Inflow*) are used as instruments, and in the aggregate supply relation in (12), the temperature (*Temp*) and the length of a day (*Daylength*) are used as instruments. Both equations are estimated using autocorrelation and heteroscedasticity consistent standard errors.

First, the aggregate demand function in (11) is estimated for the whole period using five lags. Insignificant variables are, thereafter, removed from the regression specification and a parsimonious model is derived. See Table A.4 in the Appendix for results for the whole period as well as for each subperiod in the integration process, which show that lagged quantities (Q) have a positive impact on current demand for electricity. The estimates for the cointegrating vectors show that the current price (P) has a negative impact on demand as expected. In addition, increased temperature (*Temp*) and longer days (*Daylength*) cause the demand for electricity to fall.

Second, the aggregate supply relation in (12) is estimated including $Q^* = \frac{Q}{\delta Q/\delta P}$ in the regression specification. Since the price variables are non-stationary, an error-correction model is used to estimate the supply relation, and as the error-correction term, we use the first lag of the cointegrating vector. The aggregate supply relation is estimated for the whole period, and a parsimonious model is derived in the fashion presented above, which is estimated for each subperiod in the integration process. See Table A.5 in the Appendix for results, which show that an increase in the inflow of water to reservoirs (*Inflow*) lowers the price of electricity, while increased use of residual electricity (*Resel*) increases the price. The error-correction term (*CV1*) indicate a slow error-correction in line with previous literature (see Hjalmarsson [11] and Vassilopoulos [19]).

Finally, the estimates of the degree of market power, λ, are presented in Table 4.[6]

[Table 4 about here.]

The results show that suppliers of electricity have a small, but statistically significant, degree of market power in the Nordic power market during the whole

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[6] λ is supposed to be between 0 and 1 as in Table 4. However, since no minus sign is included in the regression equation, λ changes sign. Therefore, in Table A.5, λ is supposed to be between 0 and minus 1.

period under study. However, the degree of market power has been reduced as the market has expanded, and in the last subperiod, the market power parameter is not significantly different from zero. In economic terms, the estimated market power parameters indicate small markups over marginal cost. Calculating the implied Lerner index gives a markup of less than one percent in the different subperiods and an even smaller markup for the aggregated sample period.[7]

4 Discussion

The purpose of this paper has been to examine whether the common wholesale electricity market has been competitive or if suppliers of electricity have had market power. Moreover, because the evolution from national markets to a multi-national market has taken place step by step, this paper also examines if the degree of market power has changed as the Nordic electricity market has expanded.

While previous studies of market power in the Nord Pool area (see Hjalmarsson [11] and Vassilopoulos [19]) have not found any evidence of market power, our study, which is preformed on a more comprehensive data set, indicate that there has been a small, but statistically significant, degree of market power during the whole period under study. In addition, our results also show that the degree of market power has been reduced as the market has expanded.

However, the implied Lerner index results in a markup of less than one percent over marginal cost, meaning that the impact of market power on the electricity price has not been that severe. Steen [17] examined the Norwegian market with results similar to ours and concluded that "the results are probably more a word of warning that we should be careful to allow more concentration in this market."

Most likely, there are several reasons why the markup has been low, one of them being the threat of entry. Wolfram [20] argues that there are two reasons why firms in the UK have not utilized all potential market power: (i) the threat of market interventions from the authorities; and (ii) the threat of entry into the market. Although her results may not be directly transferable to the Nordic market, a recent study by Edin [7] argues that it is possible that the threat of entry have kept the price close to marginal cost also in the Nordic electricity market.

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[7] The implied Lerner index is defined as $\frac{P-MC}{P} = -\frac{\lambda}{\varepsilon}$, where ε is the absolute value of the demand elasticity (see Steen [17]).

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Table 1: Integration process in the Nordic power market

Country	*Date for affiliation*	*Date for complete integration*
Norway	January 1, 1993	January 1, 1993
Sweden	January 1, 1996	January 1, 1996
Finland	December 29, 1997	March 1, 1999
Western Denmark	July 1, 1999	March 1, 2002
Eastern Denmark	October 1, 2000	March 1, 2002

Table 2: Variables, definitions and data sources

Variable	*Definition and data source*
P	Nord Pool's spot price at the system level, NOK/MWh. Source: Nord Pool ASA
Prod	Weighted average of the countries' industrial production indexes using the countries' GDP shares as weights. Sources: Statistics Norway, Statistics Sweden, Statistics Finland, Statistics Denmark and OECD
Temp	Weighted average of the participating countries average temperatures, where the weights are the countries' GDP shares, and the participating countries' average temperatures, in turn, are weighted averages of the average temperatures in selected cities, where the weights are the cities' populations.^{a} Sources: Nord Pool ASA and SMHI
Daylength	Number of hours the sun is above the horizon in Gothenburg, Sweden. Source: www.stjarnhimlen.se
Inflow	Inflow to water reservoirs, recalculated from water inflow to the water's energy content in MWh. Sources: Nord Pool ASA and SYKE
Coal	Price of coal used to generate electricity, USD/MWh. Source: The McCloskey Group
Oil	Price of Brent crude oil used to generate electricity, USD/MWh. Source: tonto.eia.doe.gov/oog/ftparea/wogirs/xls/psw14.xls
Resel	Residual electricity traded at Nord Pool's spot market in relation to total electricity production. Source: Nord Pool ASA
Turnover	Number of MWh traded at Nord Pool's spot market. Source: Nord Pool ASA
Market share	The market share of Nord Pool's spot market measured as the turnover at the spot market in relation to total electricity production. Source: Nord Pool ASA
Q	Detrended turnover at Nord Pool's spot market measured by regressing the turnover at the spot market on its market share, where the residuals are used as detrended turnover. Source: Nord Pool ASA

Note: ^{a} The cities in Sweden are Stockholm, Gothenburg, Luleå and Östersund; the cities in Norway are Oslo, Bergen, Trondheim and Tromsø; the cities in Finland are Helsinki and Ivalo; and the cities in Denmark are Copenhagen and Billund.

Table 3: Descriptive statistics

Variable	$9601-0416$	$9601-9908$	$9909-0209$	$0210-0416$
P	178.17	181.06	135.08	234.85
	(85.45)	(79.09)	(44.50)	(103.07)
Prod	96.21	90.96	98.51	100.72
	(8.09)	(6.68)	(7.48)	(6.46)
Temp	6.83	5.95	7.61	7.05
	(7.46)	(7.56)	(6.96)	(7.91)
Daylength	86.06	85.25	86.41	86.76
	(26.99)	(27.23)	(27.23)	(26.51)
Inflow	$3.66E+06$	$3.43E+06$	$4.24E+06$	$3.20E+06$
	$(2.98E+06)$	$(2.92E+06)$	$(3.02E+06)$	$(2.92E+06)$
Coal	37.91	39.93	34.73	39.43
	(8.17)	(5.60)	(4.40)	(12.85)
Oil	90.31	74.55	95.44	106.35
	(21.85)	(18.70)	(20.25)	(10.23)
Resel	0.11	0.08	0.11	0.16
	(0.05)	(0.04)	(0.02)	(0.04)
Turnover	$1.66E+06$	$9.31E+05$	$1.86E+06$	$2.43E+06$
	$(7.43E+05)$	$(2.44E+05)$	$(4.56E+05)$	$(5.73E+05)$
Market share	0.25	0.17	0.26	0.34
	(0.07)	(0.03)	(0.03)	(0.04)
Q	0.00	$-3.63E+05$	$8.37E+05$	$-6.47E+05$
	$(3.22E+05)$	$(2.79E+05)$	$(3.25E+05)$	$(3.52E+05)$
*P*Temp*	$1.00E+04$	984.86	901.88	$1.16E+04$
	$(1.49E+04)$	$(1.62E+04)$	(985.65)	$(1.85E+04)$
*P*Daylength*	$1.46E+05$	$1.51E+05$	$1.13E+05$	$1.86E+05$
	$(7.25E+04)$	$(8.63E+04)$	$(4.82E+04)$	$(5.44E+04)$
Number of observations	432	164	157	111

Note: 9601-0416 refer to the period week 1, 1996, to week 16, 2004, etc.

Table 4: The degree of market power

Variable	$9601-0416$	$9601-9908$	$9909-0209$	$0210-0416$
Q^*	$6.97E-05^*$	$5.56E-04^{**}$	$2.02E-04^*$	$-7.58E-04$
	$(1.47E-05)$	$(2.38E-04)$	$(5.26E-05)$	$(2.06E-03)$

Note: 9601-0416 refer to the period week 1, 1996, to week 16, 2004, etc. * Significant at the 1% level, ** significant at the 5% level.

Appendix

Table A.1: Augmented Dickey-Fuller unit root tests

Variable	$I(0)$	*Lags*	$I(1)$	*Lags*
P	-2.73	7	-9.10^*	6
Prod	-2.94	9	-11.82^*	8
Temp	-6.05^*	7	–	–
Inflow	-7.50^*	2	–	–
Coal	-1.85	14	-3.49^*	13
Oil	0.24	6	-10.57^*	5
Resel	-3.20	5	-9.13^*	4
Q	-3.21^*	8	–	–
*P*Temp*	-4.18	9	–	–
*P*Daylength*	-2.45	3	-11.82^*	2

Note: * Significant at the 1% level. The critical values are from Fuller [8].

Table A.2: Multivariate cointegration test of the demand function

	Demand function^b		*95% critical value*
0 cointegration vector	71.69^*		29.70
$r = 0$			
1 cointegration vectors	30.04^*		15.40
$r \leq 1$			
2 cointegration vectors	5.93^{**}		3.76
$r \leq 2$			
Standardized eigenvectors			
Variable	*P*	*Prod*	*P*Daylength*
CV1	1.00	0	−0.01
CV2	1.00	853.46	0
Separability tests			
$H_0 : \beta_{1,P} = \beta_{2,P} = 0$	28.17^*		
$H_0 : \beta_{2,Prod} = 0$	30.18^*		
$H_0 : \beta_{1,P*Daylength} = 0$	26.32^*		

Note: ^{b} k=4 number of lags, n=428 number of observations. * Significant at the 1% level, ** significant at the 5% level, *** significant at the 10% level. The critical values are from Osterwald-Lenum [16].

Table A.3: Multivariate cointegration test of the supply relation

	Supply relation^c		*95% critical value*
0 cointegration vector	31.30**		29.70
$r = 0$			
1 cointegration vectors	16.23**		15.40
$r \leq 1$			
2 cointegration vectors	6.21**		3.76
$r \leq 2$			
Standardized eigenvectors			
Variable	*P*	*Oil*	*Resel*
CV1	1.00	-1.69	-110.93
CV2	1.00	-51.07	$-2.36E+05$

Note: ^{c} k=2 number of lags, n=430 number of observations. * Significant at the 1% level, ** significant at the 5% level. The critical values are from Osterwald-Lenum [16].

Table A.4: Estimation results of the demand function

Variable	$9601-0416$	$9601-9908$	$9909-0209$	$0210-0416$
Constant	$4.60E+05^{*}$	$3.43E+05^{*}$	$7.25E+05^{*}$	$4.95E+05^{**}$
	$(9.41E+05)$	$(1.28E+05)$	$(1.53E+05)$	$(2.36E+05)$
Q(-1)	0.78^{*}	0.90^{*}	0.52^{*}	0.67^{*}
	(0.04)	(0.03)	(0.05)	(0.11)
Temp	$-4.65E+04^{**}$	-962.25	$-1.17E+05^{*}$	$-5.29E+04$
	$(1.85E+04)$	$(1.41E+04)$	$(2.51E+04)$	$(4.09E+04)$
Daylength	$-3.21E+04^{*}$	$-1.58E+04^{*}$	$-4.97E+04^{*}$	$-4.67E+04^{*}$
	(495.68)	(443.86)	(788.63)	$(1.21E+04)$
CV1	-712.57^{*}	-291.97^{***}	$-1.01E+04^{**}$	-889.17^{*}
	(189.48)	(174.23)	(417.72)	(188.69)
CV2	-151.34^{**}	-208.56^{**}	-211.05^{**}	-46.80
	(73.48)	(100.24)	(103.96)	(183.89)
R^2	0.91	0.96	0.95	0.81
Long-run parameters				
Constant	$2.10E+06^{*}$			
	$(5.24E+05)$			
Temp	$-2.12E+05^{*}$			
	$(6.53E+04)$			
Daylength	$-1.46E+05^{*}$			
	$(3.40E+04)$			
CV1	$-3.25E+04^{*}$			
	$(1.20E+04)$			
CV2	-689.73^{**}			
	(352.57)			
Estimates of the individual components in CV1 and CV2				
P1	$-3.25E+04$			
PD	325.00			
P2	-689.73			
Prod	$-5.89E+05$			

Note: 9601-0416 refer to the period week 1, 1996, to week 16, 2004, etc. * Significant at the 1% level, ** significant at the 5% level, *** significant at the 10% level.

Table A.5: Estimation results of the supply relation

Variable	$9601-0416$	$9601-9908$	$9909-0209$	$0210-0416$
Constant	4.12^{*}	4.89^{***}	1.08	5.01
	(1.48)	(2.56)	(2.13)	(3.99)
ΔQ	$4.75E-05^{***}$	$1.99E-05$	$3.02E-05$	$1.96E-04^{**}$
	$(2.49E-05)$	$(2.93E-05)$	$(2.57E-05)$	$(1.01E-04)$
Q^*	$-6.97E-05^{*}$	$-5.56E-04^{**}$	$-2.02E-04^{*}$	$7.58E-04$
	$(1.47E-05)$	$(2.38E-04)$	$(5.26E-05)$	(0.00)
Inflow	$-9.28E-07^{*}$	$-1.04E-06^{**}$	$-8.99E-07^{**}$	$-2.08E-07$
	$(3.11E-07)$	$(4.53E-07)$	$(4.44E-07)$	$(7.40E-07)$
Δ*Resel*	763.98^{*}	441.57	639.07^{*}	$1.57E+04^{**}$
	(288.12)	(278.24)	(173.88)	(686.12)
CV1(-1)	-0.06^{***}	-0.04^{***}	-0.07^{*}	-0.10
	(0.04)	(0.02)	(0.03)	(0.08)
R^2	0.16	0.15	0.18	0.28
Estimates of the individual components in CV1(-1)				
P(-1)	-0.06			
Oil(-1)	0.10			
Resel(-1)	6.66			

Note: 9601-0416 refer to the period week 1, 1996, to week 16, 2004, etc. * Significant at the 1% level, ** significant at the 5% level, *** significant at the 10% level.