The System Price of Electricity on Nord Pool

A Matter of Fundamental Factors?

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Abstract

The purpose of this thesis is to examine what fundamental factors affect the System price of electricity on the Nordic electrical energy market, Nord Pool and to quantify the relationship. It is of value to all actors in this market to be able to accurately predict the price in order to make good trading decisions. The factors that were included in our model are the price of carbon emission rights, import to the Nordic area electrical exchange area, the price of coal, average temperature, nuclear power deviation from average, water reservoir deviation from average, economic trend and the USD/EUR exchange rate.

The method used is a quantitative analysis of a time series using linear regression with the Ordinary Least Squares (OLS) method and a Generalized Least Squares (GLS) to take into account the presence of serial correlation in the data.

The overall fit of the model was satisfying and all explaining variables affected the System price according to theory. All variables except nuclear deviation from its average turned out to be significant. The GLS model supported the OLS estimates and gave the same results as the OLS except that the variable for economic trend also became insignificant.

The model proved satisfying. The predicted System prices generated by the model proved to be quite similar to the actual System price. The conclusion from the results is that one can evidently make predictions on future System prices using observed fundamental factors.
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1. Introduction

1.1 Background

The feat of converting energy into electricity is one of the main contributors to the industrialization and the development from subsistence agriculture to prosperous and highly developed economies. This is especially true for the Nordic countries that have a cold climate and energy intensives industries. The refined form of energy, electricity, has been used for over 100 years and has changed society to the core and increased the standard of living in the countries using it. Electricity continues to contribute to economic growth, welfare and is a cornerstone of the modern global economy. Although the supply itself is quite reliable and something that is taken for granted, the price of electricity is something that is always a topic of discussion. The price of electricity affects the disposable income of individuals and the price input factors for firms that make an economy sensitive to volatility in the price of electricity (Vattenfall, 2011).

The focus of this paper is the Nordic power exchange that is a highly developed market for trade of electrical energy. Before there was an open market, electricity in the Nordic countries was supplied by state-owned monopolies. In 1990, Norway formed the basis for a deregulated market and in 1996 Nord Pool was formed in cooperation with Sweden. It became the world’s first multinational exchange of electricity. In 2000 the Nordic market for electricity became fully integrated, with the exception of Iceland. Nord Pool provides a market for buyers and sellers of electrical energy and is the central counter party which guarantees settlement for trade. Nord Pool also provides a financial market where actors can manage risk over time. The spot price is named the System price and is the reference price for all financial instruments on the Nordic power exchange (Nord Pool, 2010).
Figure 1 shows that the System price has been quite volatile since the Nord Pool was instated. The long-term trend of the price is positive and the price has been characterized by more extreme peaks after 2002. A reason why the price can suddenly spike or drop is because electrical energy cannot be stored and has to be consumed at the same time that it is produced (The Swedish Energy Agency, ER 2006:13, p. 7). This means that a sudden drop in production capacity, if for example a nuclear reactor is temporary closed, instantly decreases the available supply and creates an excess demand which makes the price surge.

It is relevant to the actors on Nord Pool to understand what factors influence the System price of electricity regardless if their intention is investing, hedging or speculating in the price. Moreover, this information is also useful for firms and individuals who are not direct players on Nord Pool, for example consumers. The results might also be of some relevance politically, in relation to policy-making. Electrical energy is an input factor in production that affects the cost for firms and it is an more or less unavoidable cost of living for individuals. The value of a greater understanding of the movements of the System price lies increasing the ability to maximize profits or minimize costs for all players.
The development on the Nordic electricity market has led to a broad discussion of the functioning of the electricity market. The profits of the market actors as well as the price formation itself are two topics that are frequently debated (The Swedish Energy Agency, ER 2006:13, p. 1). Generally, one could assume that the introduction of competition on a previously deregulated market would yield lower prices, or prices that move towards the marginal cost of units produced. Some studies suggest that this is not the case. For example, Duckworth et al. (1998) studied the deregulated market for electricity in Pennsylvania, USA. The study compared the observed prices to the perfectly competitive prices that what would occur using Nash equilibrium style bidding. The results showed that there is a negative relation between number of firms and market price of electricity. However, when compared to the perfectly competitive price there is still a significant mark-up even with low market concentration (Duckworth et al., 1998, pp. 1-2). Another study that looks into the problems with energy market pricing is Borenstein (2002). Borenstein studies the electricity market of California but argues that the problems with volatile prices and profits are often the result of the design of the energy market regardless of location. The problem lies in that demand for electricity is almost completely insensitive to the fluctuations in price while supply is constrained at peak times. Further, Borenstein argues that the solution to the problems in electricity market pricing is apply a policy that encourages price responsive demand and in the case of California – long term wholesale contracts on electricity (Borenstein, 2002). Even though Borensteins solution to the problem is not directly applicable to the Nordic market it highlights some of the issues with electricity pricing, demand is insensitive to prices and supply is restricted structurally. We will outline the pricing process for the Nordic market in Section 2.1.

1.2 Purpose

The purpose of this thesis is to examine what fundamental factors affect the System price of electricity on Nord Pool and to quantify the relationship. The aim is to derive a model that explains and predicts price movements in a satisfying way. If the price can be explained by fundamental factors, actors must be price takers. If not, the actors could individually or in cooperation set the price, rendering the fundamental factors
subordinated. The research question is: Can the System price on Nord Pool be explained by fundamental factors?

This paper is limited to the time period 2000-2010. The reason is that after the year 2000, the market was fully integrated and because 2010 is the last completed year. This paper is limited to the Nordic market for two reasons, the existence of quality data and due to the previous knowledge the authors have about the Swedish and Nordic markets. If the fundamental factors do not explain the System price, possible reasons for this occurrence will be discussed. The fundamental factors are limited to relevant factors supported by the theory and those that are generally accepted in the electrical energy industry.

1.3 Method

This thesis uses a quantitative approach with times series data from 2000 to 2010. The method used is an Ordinary Least Squares (OLS) linear regression. This method was chosen because it is a generally accepted and straightforward method of making statistical inference. Due to serial correlation in the error term a Generalized Least Squares (GLS) method is also employed. Theoretically, the GLS method removes first-order serial correlation of an equation and restores the minimum variance property. The equation is thus transformed to meet the Classical Assumptions. In order to remove the serial correlation the equation is multiplied with the coefficient of serial correlation ($\rho$) and lagged one time period. $\rho$ is estimated using the Chochrane-Orcutt method. It is a two-step iterative technique where the residuals of the OLS regression are used as a dependent variable and lagged version of the residuals as independent. The correlation between the lagged and actual value of the residuals is then used as $\rho$ in the GLS equation. The results of the OLS and the GLS was compared to examine if the results are valid.

If the market is fully efficient, the market price follows a random-walk and the development of a predictive model is superfluous (see section 2.3). In order to test whether or not the System price follows a random-walk, a Dickey-Fuller test was performed. The Dickey-Fuller test examines the hypothesis that the variable in question has unit root. If a unit root exists, then the variable follows a random walk. A random
walk variable is non-stationary. A random walk is a time-series variable where next period’s value equals this period’s value plus a stochastic error term. Suppose that $Y_t$ is generated by an equation which includes only past values of itself, an autoregressive equation where $v_t$ is the error term.

$$Y_t = Y_{t-1} + v_t$$

If $\gamma < 1$ then the expected value of $Y_t$ will eventually approach zero. If $\gamma > 1$ then the expected value of $Y_t$ will continually increase. However, if $\gamma = 1$ then the expected value of $Y_t$ does not converge on any value. The situation where $\gamma = 1$ is called a unit root and if the variable has a unit root, the variable follows a random walk (Studenmund, 2006, pp. 434-435).

The Dickey-Fuller tests whether or not $\gamma$ is equal to 1, i.e. the existence of a unit root (Studenmund, 2006, pp. 436-438).

$$Y_t = b_0 + b_1 Y_{t-1} + v_t$$

Where $b_1 = \gamma - 1$. The null hypothesis is that $Y_t$ contain a unit root and the alternative hypothesis is that $Y_t$ is stationary. If $Y_t$ contains a unit root then $\gamma = 1$ and $b_1 = 0$. If $Y_t$ is stationary then $\gamma < 1$ and $b_1 < 0$. We used a one-sided $t$-test on the hypothesis that $b_1 = 0$:

$$H_0 : b_1 = 0$$
$$H_A : b_1 < 0$$

A standard $t$-table cannot be used, therefore a $t$-table which is adapted to suit the Dickey-Fuller test was used (Toronto University, “Statistical Tables for Unit Root Tests”).

1.4 The Functioning of the Electrical Energy Market

The purpose of this thesis is to examine what fundamental factors affect the System price of electricity on the Nordic electrical energy market, Nord Pool and to quantify the relationship. However, for the electricity consumer the price of electricity includes many additional costs such as distribution fees, taxes and other costs included in the specific contract the consumer have. While distribution fees and taxes are regulated by the state, the electrical energy itself is the only part of the total cost that is exposed to
competition. Each electricity consumer is free to choose from which electricity supplier they buy their electricity. The electrical suppliers can set which ever price they like but they must all buy the electrical energy from Nord Pool where the going rate is the System price (Swedenenergy). Figure 2 shows how electricity is transported from the electricity producer via the national grid, regional networks, and local networks to the electricity consumer. The electricity producers sell their electricity via the Nord Pool electricity exchange to an electricity supplier (Swedish National Grid, About Us).

**FIGURE 2.** An Overview of the Actors on the Electrical Energy Market

The Nordic Electricity Exchange is divided into a physical market, Nord Pool Spot, and a financial market, NASDAQ OMX Commodities. On the financial market actors can fix the price to avoid the variations of the System price. This is achieved through different financial instruments such as futures and forwards. Carbon emission rights are also traded on the financial market. Nord Pool Spot is divided into two sub-markets, the Elspot and the Elbas markets. The Elbas market is a continuous cross border intra-day market that covers both the Nordic countries, Germany, and Estonia where adjustments to trade is done in the day-ahead market are made until one hour prior to delivery. On the Elspot market, hourly power contracts are traded daily for physical delivery the next
day. The price calculation is based on the balance between bids and offers from all market participants (Nord Pool Spot).
2. Theory

2.1 Supply and Demand

A simple supply and demand model can describe the Nordic market for electricity. Sellers and buyers participate in an auctioning process regarding the next 24-hour period. Volume and price is specified by the actors and for each hour during the following day the actor’s bids are aggregated into supply and demand. The combination of price and quantity where the supply and demand intersects results in the market-clearing price which is the hourly System price. All actors that have submitted sales orders that are equal to or less than the equilibrium price will get to sell at the market price. Similarly all actors who have submitted buy orders equal to or higher than the equilibrium price get to buy at the market price (The Swedish Energy Agency, ER 2006:13, pp. 3-4). Figure 3 shows the relationship between supply and demand on Nord Pool Spot. In order to satisfy fluctuating demand, a broad variety of production techniques are required. The supply consists of wind power, hydro power, nuclear and condensing plants. The condensing plants use oil, coal and gas to generate electrical energy. The variable cost of the different production costs varies between the different types of installations. Wind and hydro power have variable costs of almost zero and condensing plants which produce electricity with gas turbines have very high variable costs (Nord Pool Spot).
The equilibrium price is equal to the last unit producers are willing to supply or the last unit consumers are willing to buy. In other words, the cost of producing one unit using the most expensive production technique or the price the consumers are willing to pay for the last unit of electricity in order to satisfy their demand. Because electrical energy cannot be stored it has to be delivered at the precise moment it is needed by the consumer, demand is very inelastic. In many markets consumers can easily find substitutes if the price of a certain good is too high. In the electrical energy market consumers can install other means of heating or even own small-scale power plants. This is however costly which explains the inelasticity of demand further. The components of supply and demand are displayed in Figure 4 and Figure 5. From Figure 4 it can be concluded that manufacturing firms, service firms and household are the major consumers of electricity. Losses stem from the inability of storing electricity when supply is greater than demand. Unfortunately, this data was only available for Sweden. Figure 5 shows that hydro power is the main source of electricity in the Nordic countries, followed by nuclear power and fossil fuels. Wind power and other renewables (biofuels, solar power, renewable waste and recycling fuels) are not major sources of electricity.
FIGURE 4. The Composition of Demand, Sweden

Source: Statistics Sweden

FIGURE 5. The Composition of Supply, Nordic Countries

Source: Nord Pool Spot
2.2 Price Affecting Factors

Since the electricity market of the Nordic countries has a price setting mechanism that is characterized by supply and demand, the factors that affect supply and demand are in turn the factors affecting the price. Both authors of this paper have worked in the electricity industry and have gained experience about what factors affects the price. The factors usually discussed as having most impact include average temperatures, price of fossil fuels (coal, oil and gas), business cycles, the Nordic water reservoir content and the status of nuclear reactors. The Swedish Energy Agency listed two of the factors affecting the demand side in their report ER 2006:13, namely temperature and economic trend. In the same report the agency listed supply side factors that affect the cost of producing electricity which among others included hydrological factors, trade with continental Europe, fossil fuel prices, the competitive situation and the emissions trading scheme starting in 2005. These factors are consistent with our initial view of the factors that may affect the System price on Nord Pool.

There is limited empirical evidence of the effect which the factors included in this study has on the System price. There is some evidence for temperature and the water reservoir levels (Torro, 2008), the other factors discussed are recognized by market participants and regulators as having an impact (positive or negative) on the price but the relation is not quantified. While there are several studies related to the electricity markets around the world, there are few which we can relate to in this study since the focus of these studies is not to quantify the relationship between the spot price and fundamental factors.

2.2.1 Demand Side Factors

Temperature

The demand of electricity has been shown to be affected by weather variables in several studies. Specifically, Sailor & Muñoz (1997) who studies the U.S. market find that of the weather variables studies, temperature is the most significant in the estimation of demand for electricity. Pardo et al. (2002) who studies the Spanish market, find that temperature has great influence on the demand of electricity. In the Nordic market, the temperature is also of significance which is recognized both by authorities and market.
In an official report issued by the Swedish Government, the authors claim that the demand side variation is largely affected by the outside temperature since a large proportion of electricity is used for heating (SOU 2004:125, p. 103). However, Torro (2008, p.8) holds that the relationship is not obvious. Low temperatures increase the demand for heating but high temperature increase the demand for cooling, both leads to an increased demand for electricity. However, in the Nord Pool area, the increased demand for electricity only appear in low temperatures. Johnsen (2001) show that changes in temperature is the main contributor to seasonality of the System price, that is higher prices in the winter and lower prices in the summer. We also argue that it could be the case that cold weather will lead to more people staying indoor and thus use more electrical devices but this consumption becomes peripheral when compared to the consumption for heating.

Economic Trend

As mentioned above, The Swedish Energy Agency discuss the macro economic trend as a major influence on the demand of electricity (ER 2006:13. p. 6). However, the authors do not elaborate on what they mean with economic trend. We interpret this as general business cycles where increased consumption and production will generate a higher demand for electricity.

Export and Import to and from the The Electric Exchange Area (EEA)

The EEA consists of Denmark, Finland, Norway and Sweden. If there is a lack of supply on the Nordic exchange it will lead to import of electricity that will include importing more expensive production mainly from Germany. This will have a positive effect on the System price (SOU 2004:129, p. 107-108). Export and the System price should be negatively correlated since the existence of exports means that there is an excess supply which can be sold to countries outside the EEA. However, it is possible that exports are positively correlated to the System price since a higher demand outside the EEA would lead to a higher aggregated demand on Nord Pool. Due to the uncertainty of the effect of exports, only imports are included in the model.
2.2.2 Supply Side Factors

Carbon Emission Rights
The emission rights price affects the production cost of electricity produced by plants that emit CO$_2$. “The need for emission rights raises producers’ marginal cost for fossil-based power production and thereby the price of electricity when fossil energy is used on the margin” (The Swedish Energy Agency ER 2006:13, p. 25).

Nuclear Production
The nuclear production will together with wind and hydropower contribute to cheaper production compared to fossil fuels. When the low cost production is on a large scale, there will no demand for high cost production alternatives. Since the marginal cost of the most expensive produced unit of electricity is the going rate on the market, increased nuclear production will contribute to a lower price.

Nordic Water Reservoir Content
Even though electricity cannot be stored, it is possible to store water in hydro power plants which can be used to produce electricity. The Nordic water reservoir indicates how much hydro power is available. Since the supply in the Nordic market consists of 56 percent hydro power (see Figure 5), this should be a factor with large influence on the price formation. This is confirmed by Torro (2008) who hold that the reservoir levels are indeed an important factor in the determination of the spot price. Torro (2008, p. 3) also argues that if the reservoir levels are seen as inventory of electricity, shocks to supply and demand will affect the price to a larger or lesser extent depending on levels of hydro power available. Specifically, when reservoir levels are high, shocks are easily offset. However, when the levels are low, a shock will be severe and not as easily absorbed. Therefore, higher levels of reservoir content should have a negative affect on the System price since the electricity available on short notice is greater. Low levels of reservoir content indicates that a rapid increased in demand would have to met by higher cost production alternatives.
Fossil Fuel Prices

Fossil fuel prices include mainly oil, coal and gas. The fossil fuels are burned in condensing plants and is the most expensive production method. These commodities are used in the production of electricity when other means of production cannot meet demand. The cost of production of electricity with fossil fuels will depend on the price of the respective commodities. Therefore, a higher price of fossil fuels would affect the System price positively.

The US Dollar Exchange Rate

Fossil fuels priced in US dollars will become cheaper with a depreciating dollar exchange rate. This would mean that the marginal cost of producing power with fossil fuels would fall with a depreciating dollar and consequently affect the System price of electricity. The exchange rate will affect the System price even more in times of greater imports of electricity. Germany is the biggest trading partner for the EEA and their production depends mainly on coal. The exchange rate with the greatest effect on the System price should therefore be USD/EUR since coal is traded in US dollars and Germany’s currency is the Euro. From 2000 to 2010 the US dollar has depreciated in relation to the Euro making input factors relatively less expensive if the absolute cost for input factors are held constant.

In summary, the theoretical specification and expected signs is given below.

\[
\text{System price}_i = f\left(\text{CMR}_i,\text{NP}_i,\text{WRC}_i,\text{PC}_i,\text{XRT}_i,\text{TEMP}_i,\text{IMP}_i,\text{PI}_i\right)
\]

2.3 The Efficient-Market Hypothesis

A market that fully reflects all information is defined as efficient, i.e. all information (inside and public) is absorbed in the price on the market. If this holds, it is not possible to consistently receive returns that are disproportional to the amount of risk in a certain investment. Fama (1970) developed three forms of the efficient-market hypothesis where different information sets are considered. First, weak form efficiency in which the information set is historical data. Excess returns cannot be earned in the long-run based on past prices. Second, semi-strong form efficiency, in which the information set
is all publicly available information such as announcements of annual earnings, stock splits, etc. Investors cannot make excess returns based on this information since prices adjust rapidly. Third, strong form efficiency, in which the information set is all available data relevant for price formation and it is rationally processed by the market. No one can consistently earn excess returns based on any available information. In other words, prices follow a “random walk” and predictions attempted by this paper is not meaningful.

For the electrical energy market this means that excess returns can neither be earned based on historical System prices nor public information such as the reservoir content or the price of coal. However, both in Sweden and internationally electricity prices seems to suffer from seasonal effects of some sort. Thomas et al, find that the Australian electricity market suffer from seasonal effects in time of day, day of week and monthly although the monthly effect is significant to a lesser degree (Thomas et al., 2011, p. 355). Without looking further into hourly or daily seasonal effects, Figure 6 shows that the System price has a seasonal character which is in violation of the efficient market hypothesis. Deng (2006) empirically examines this and concludes that Nord Pool is in fact not an efficient market. The inefficiency is explained by the intra- and inter-year serial correlation in prices of electricity, i.e. its seasonal component. This means that information of past prices that can actually be used to predict future prices. Since information of past prices and publicly available information can be used to predict future prices, a model that incorporates this information can be of great value.
FIGURE 6. Average monthly System price, 2000-2010

Source: Nord Pool Spot

2.4 Abuse of Market Power

In this paper, the hypothesis is that the System price can be explained by fundamental factors. If this assumption is to holds it is important that the actors do not have enough market power to affect the price, or that they choose not to. If that were the case, it would result in a market where market actors were not price takers and the System price would be result of both fundamental factors and price decisions. Abuse of market power would thus render our model less accurate. The Energy Markets Inspectorate investigated this matter in 2006 (ER 2006:13) using a HHI index and residual supply index. The conclusion was that at certain times a given producer may be needed for the market to clear which gives the particular producer a position of power. However, the results does not show whether the market power has been abused or not. Even though the above mentioned report indicates a moderate market concentration and, at times, high residual demand facing the biggest suppliers, there is no conclusion that market power abuse is present on this particular market.
3. Data

Temperature
The variable representing temperature in the Nordic countries consists of the mean temperatures of Oslo, Stockholm and Helsinki\(^1\). The reasoning behind using these cities is simply that a more densely populated area will have more consumers using more heating when temperatures are low. The mean temperatures in Stockholm were calculated from daily mean temperature to monthly, the mean temperatures from Oslo and Helsinki was originally on a monthly basis. The three monthly means were combined into one single mean which represents the Nordic average temperature. The data was gathered from the meteorological institutes of Finland, Norway and Sweden.

Economic Trend
In order to capture the effect of increased economic activity, a production index compiled by OECD (2010) was used. The index is has a base year of 2005 and includes the production of the total industry of a country. Monthly data was available for Denmark, Finland, Norway and Sweden. The monthly mean of these indices was calculated to create a Nordic production index.

Export and Import to and from the The Electric Exchange Area (EEA)
Only weekly data on the export and import of electricity in the EEA was available. Therefore, this data was transformed to a monthly format. The unit of this variable is GWh\(^2\). The data was gathered from a server owned by Nord Pool.

Carbon Emission Rights
The data on the carbon emission rights data was gathered from the same server as the data on import and export. The trade of carbon emissions rights on the 11th of February 2005. Before this date all values are zero because previous to that, the carbon emission rights were not a cost for the producers of electricity. The price of carbon emission rights was by calculated by taking the monthly mean of daily closing prices of one year contracts.

\(^1\) Copenhagen was omitted due to the cost of the data.
\(^2\) One Giga Watt hour (GWh) is equal to one million Kilo Watt hours (kWh).
Fossil Fuel Prices
Since coal is the most commonly used fossil fuel, it was used to represent the price of fossil fuels. A fossil fuel index was created and tested with all three variables that proved worse than coal alone. Fuel price data was gathered from Index Mundi which complied the data from the International Monetary Fund. Monthly data was available and no transformation was needed.

US Dollar Exchange Rate
The currency exchange rate data was gathered from OANDA, monthly data was available and no transformation was performed.

Nuclear production
Nuclear production has a clear seasonal variation. This is due to the lower levels of hydrological power available during winter. In order to erase this seasonal variance the deviation from the monthly average was calculated. The variable is expressed as the deviation in percentage from the average. Only weekly data was available and it had to be transformed in to monthly data, it was gathered from Nord Pool’s server.

Nordic Water Reservoir
The water reservoir data also showed seasonal variance. The water reservoirs are usually depleted during the winter and repleted again during spring. The seasonal variance was dealt with by creating a deviation variable in the same way as with nuclear production. The it was gathered from Nord Pool’s server and was only weekly data in a weekly format and had to be transformed in to monthly data.

The empirical specification is as follows.

\[
\text{System price}_i = b_0 + b_1 \text{CMR}_i + b_2 \text{NP}_i + b_3 \text{WRC}_i + b_4 \text{PC}_i + b_5 \text{XRT}_i + b_6 \text{TEMP}_i + b_7 \text{IMP}_i + b_8 \text{PI}_i + \epsilon_i
\]

System price = The monthly average on Nord Pool Spot (EUR/MWh)

CMR = Carbon emission rights from February 2005 (price of a one-year contract, EUR/ton CO\textsubscript{2})
System price  =  The monthly average on Nord Pool Spot (EUR/MWh)

CMR  =  Carbon emission rights from February 2005 (price of a one-year contract, EUR/ton CO₂)

NP  =  Nuclear production in the Nordic region deviation from monthly average (percentage)

WRC  =  Water reservoir content of in the Nordic region, deviation from monthly average (percentage)

PC  =  Price of coal (USD/metric ton)

XRT  =  Exchange rate (USD/EUR)

TEMP*  =  Mean temperature in the cities of Oslo, Stockholm and Helsinki

IMP*  =  Import to the EEA (GWh)

PI*  =  Economic trend measured by production indices of the total industry of Denmark, Finland, Norway and Sweden

ε  =  the error term

* = Demand side factors, all other independent variables are supply side factors.

The descriptive statistics for the above specification is found in Table 1.
**TABLE 1.** Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. error</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>System price</td>
<td>132</td>
<td>33.379</td>
<td>14.443</td>
<td>6.350</td>
<td>81.650</td>
</tr>
<tr>
<td>Carbon emission rights</td>
<td>132</td>
<td>9.748</td>
<td>9.816</td>
<td>0.000</td>
<td>28.310</td>
</tr>
<tr>
<td>Nuclear production</td>
<td>132</td>
<td>0.098</td>
<td>0.150</td>
<td>-0.310</td>
<td>0.380</td>
</tr>
<tr>
<td>Water reservoir content</td>
<td>132</td>
<td>0.007</td>
<td>0.096</td>
<td>-0.200</td>
<td>0.150</td>
</tr>
<tr>
<td>Import to the EEA</td>
<td>132</td>
<td>307.364</td>
<td>120.630</td>
<td>28</td>
<td>652.250</td>
</tr>
<tr>
<td>Price of Coal</td>
<td>132</td>
<td>60.327</td>
<td>35.685</td>
<td>24</td>
<td>192.860</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>132</td>
<td>0.858</td>
<td>0.155</td>
<td>0.630</td>
<td>1.170</td>
</tr>
<tr>
<td>Average temperature</td>
<td>132</td>
<td>7.097</td>
<td>7.678</td>
<td>-7.290</td>
<td>20.650</td>
</tr>
<tr>
<td>Production index</td>
<td>132</td>
<td>98.188</td>
<td>4.952</td>
<td>87.650</td>
<td>108</td>
</tr>
</tbody>
</table>

Notes: For units, see page 13.
4. Empirical Findings

4.1 Initial Comments

In the econometrical analysis, several issues was in need of rectification. As previously described in the data section (chapter 3) seasonal variance was found in both nuclear production and the water reservoir content data. This problem was corrected after a simple transformation by subtracting the observed value from the average value for each month. After this transformation, the variable variable showed the monthly deviation from the average thus removing the seasonal component.

4.2 Presentation of the Results

The overall fit ($R^2$) of the model was 0.776. All independent variables had the expected sign, i.e. the independent variables affected the System price according to the theory. The VIF-values did not seem to indicate that the model suffers from multicollinearity. While there is no specific rejection region for these values, Studenmund (2006) suggest that values lower than 5 indicate absence of problematic multicollinearity. The individual factors were all significant at 5 percent, except for the nuclear production. The t-statistics yielded values larger than the critical value of 1.645 for a one sided test at 5 percent. The F-test generated a value of 50.440 which shows that the equation does indeed have a significant overall fit. The Durbin-Watson indicated that that the model contained serial correlation. Testing for positive serial correlation at 132 observations and 8 explanatory variables, the lower bound is 1.606 and upper bound is 1.829. A value larger than the upper bound does not indicated positive serial correlation and a value between the bounds renders the test inconclusive. A value below the lower bound indicates positive serial correlation, the value of the test-statistic is 0.868 which indicates positive serial correlation.
Since the OLS contained serial correlation in the error terms a GLS model was constructed to rid the equation of pure serial correlation. The GLS was used to support the results of the OLS. The results of the GLS showed that all the estimated coefficients had the correct sign, with production index being the exception. Neither the production index nor the nuclear production was significant in the GLS. After the third iteration, the estimated $\rho$ did not change.
**TABLE 2. Estimated equation, GLS (Cochrane-Orcutt)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>Std. error</th>
<th>t-test</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.207</td>
<td>0.128</td>
<td>-1.617</td>
<td>0.108</td>
</tr>
<tr>
<td>Carbon Emission Rights</td>
<td>0.479</td>
<td>0.182</td>
<td>2.631</td>
<td>0.010</td>
</tr>
<tr>
<td>Nuclear Production</td>
<td>-1.613</td>
<td>4.353</td>
<td>-0.371</td>
<td>0.712</td>
</tr>
<tr>
<td>Water Reservoir Content</td>
<td>-36.553</td>
<td>11.160</td>
<td>-3.275</td>
<td>0.001</td>
</tr>
<tr>
<td>Price of Coal</td>
<td>0.162</td>
<td>0.046</td>
<td>3.515</td>
<td>0.001</td>
</tr>
<tr>
<td>Exchange Rate</td>
<td>25.216</td>
<td>11.073</td>
<td>2.277</td>
<td>0.024</td>
</tr>
<tr>
<td>Average Temperature</td>
<td>-0.443</td>
<td>0.126</td>
<td>-3.507</td>
<td>0.001</td>
</tr>
<tr>
<td>Import to the EEA</td>
<td>0.036</td>
<td>0.007</td>
<td>4.892</td>
<td>0.000</td>
</tr>
<tr>
<td>Production Index</td>
<td>-0.003</td>
<td>0.134</td>
<td>-0.024</td>
<td>0.981</td>
</tr>
</tbody>
</table>

**Notes:** N = 132. Dependent variable System price (EUR/MWh).
A Dickey-Fuller test was performed in order to test for weak form efficiency. The null hypothesis is that $Y_t$ contain a unit root and follows a random walk ($\beta_1 = 0$) and the alternative hypothesis is that $Y_t$ is stationary and does not follow a random walk ($\beta_1 < 0$). The $t$-value is $-3.91$ which is smaller than the critical $t$-value value of $-2.58$ at 10 percent. The null hypothesis can be rejected which means a unit root is not present and that the System price does not follow a random walk, i.e. $\gamma$ is not equal to 1 (see section 1.3.).

**TABLE 3.** Dickey-Fuller test

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>Std. error</th>
<th>$t$-test</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>7.371</td>
<td>2.087</td>
<td>3.532</td>
<td>0.001</td>
</tr>
<tr>
<td>System price$_{t-1}$</td>
<td>-0.225</td>
<td>0.057</td>
<td>-3.91</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Notes: The equation is: $\Delta Y_t = \beta_0 + \beta_1 Y_{t-1} + \nu_t$
5. Analysis and Discussion

In summary, the model proved to be satisfying. The serial correlation does not seem to be an issue since the GLS model supports the OLS with the exceptions mentioned above. The aim of this paper is to derive a model that explains and predicts price movements in a satisfying way. The predicted System prices generated by the model proved to be quite similar to the actual System price, see below.

**FIGURE 7.** Predicted and actual System price

![Graph showing predicted and actual System price](image)

Source: Nord Pool and the authors’ own predictions based on this data

As can be seen above, the predictions of our model fit the historic prices rather well within our data sample. There is however some price movements that the model failed to predict. The general fault is that the predictions are less volatile, i.e. the price moved more than predicted. There are of course explanations for the extreme points in the figure. These points are accounted for in Appendix I.

In the OLS, the results show that all factors except nuclear production affect the price formation at a significance level of 5 percent. In the GLS, production index along with nuclear production proved to be insignificant. The nuclear production variable might be
insignificant due the transformation from weekly to monthly data, or the transformation from production levels measured in GWh to the percentage deviation from average. However, the same transformation was performed on other variables without rendering them insignificant. The transformation was needed in order to deal with the seasonal variation. The authors maintain that nuclear production affects the price formation at Nord Pool even though the model in this paper failed to prove this statistically. The production index proved to be significant in the OLS but was not supported by the GLS. Perhaps there is data outside the scope of this paper which can provide a better result, such as GDP or other estimators of the economic trend. Unfortunately, the GDP of the Nordic countries is only reported quarterly and a monthly estimation would be questionable at best.

The conclusion from the results is that it is possible to draw some conclusion about the direction of the System price using forecasts based on fundamental factors. The model proved fairly accurate when tested on historical data and applying the model to the future should be possible. There is one tricky element in applying the model to the future and that is estimating the independent variables. A suggestion for further studies is simplifying this process by generating a pragmatic regression model for predicting the value of the independent variables that explains the System price. It should be possible earn excess profit from predicting the price since the market is inefficient. Since the System price can be explained fairly well with fundamental factors, it is an indicator that there is little or non-abuse of market power.
References

The Internet


Data

System price, nuclear production, import to the EEA and water reservoir content gathered from Nord Pool’s server. Access was granted by contacting them via e-mail.
Carbon emission rights, gathered from NASDAQ OMX Commodities’s server. Access was granted by contacting them via e-mail. 
http://www.nasdaqomxcommodities.com/contact/.

Price of coal, compiled by Index Mundi, collected by International Monetary Fund, 


Average temperature, Stockholm, SMHI, 


Bibliography


Appendix

Appendix I - The Development of the System Price with Comments

During the time period studied, the effect a single factor has on the System price has varied. Sometimes the effect of one factor enhances the effect of another and vice versa. Below follows an illustration and explanation to the development of the System price from 2000 to 2010.

**FIGURE 8.** The Development of the System price with explanations

1. The price was low in the beginning until the mid-2000 due to heavy precipitation and increased competition.
2. With an early spring flood and a dry summer, 2002 was a bad year for hydropower in Sweden and Norway. The low production of hydropower led to an increased consumption of more expensive power sources which reflected in a very high System price.
3. During 2005 the introduction of carbon emission rights led the price to a higher level.

Source: Nord Pool and Sweden Energy
4. 2006 and 2007 was characterized by high volatility in the price on emission rights. The spring floods of these years did however yield a very good hydrological balance and the price was pressured downwards in these periods.

5. In 2007 and 2008 the price of commodities increased with the price of coal increasing rapidly that led to a higher price of electricity.

6. During the financial crisis there was a severe drop in consumption of electricity in the industry sector. The decreased demand lowered the price of electricity.

7. Low water reservoir content and an early and cold winter has recently led to a very high price on Nord Pool (Sweden Energy, Spotprisets utveckling sedan 1996)