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Efficiency in the Nord Pool Electricity Exchange

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Abstract

In recent years criticism of the electricity market has been emerging. Some claim that for Sweden, the deregulation of the power market in 1996 (and consequently Sweden's involvement in Nord Pool) has been a driving factor of rising electricity prices and a non-efficient market for electricity. Some critique is aimed at the small number of large producers of electricity, possibly making the market oligopolistic in its form and therefore ineffective. This has been analyzed, among others by Hjalmarsson (2000). Others, such as the Swedish Energy Agency, point to the criticism of the pricing mechanisms of the energy market, claiming it to be inefficient (Statens energimyndighet, 2006). This paper will focus on the efficiency of the electricity market, since it is a less explored area in the case of Nord Pool than the literature regarding market competition and therefore might have new answers as to whether Nord Pool is a well-functioning market.

The efficient market hypothesis (EMH) is a way of theoretically illustrating at what degree a market is efficient. It defines market efficiency as how prices reflect information. In the original hypothesis, put forth by Eugene Fama, there are three forms of efficiency; weak, semi-strong and strong. This paper will be focusing on the measure of weak efficiency. The weak form efficient market theory stipulates that all historical prices are incorporated in current prices. An implication of the efficient market theory is that if a market is inefficient it fails to price its product correctly since the information available is not fully incorporated in the price. It would also imply that buyers and sellers of electricity do not take all information into account.

The purpose of this study is to investigate whether or not the Nordic electricity market Nord Pool is weakly efficient within the context of the theoretical framework of the efficient market hypothesis. Additionally, the possibility of whether the market has evolved to become more efficient over time is explored. By evaluating historic spot and futures price data from an econometric perspective I aim to bring some clarity to whether there is any viability in the claims of the electricity market being inefficient.

Sammanfattning

Uppsatsens titel: Efficiency in the nord pool electricity exchange

Seminarium datum:

Ämne: Nationalekonomi/Finansiell Ekonomi

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Fem Nyckelord: Efficient market hypothesis, Stationarity, arbitrage, information, future spot parity

Syfte: Syftet med studien är att undersöka huruvida elmarknaden nord pool är effektiv i sin prissättning eller ej.

Metod: Analysen grundas på ett kvantitativt tillvägagångssätt och datan som används är historiska spot- och futurepriser från den nordiska elmarknaden.

Slutsatser: Den nordiska elmarknaden verkar vara ineffektiv ur informationell hänsyn.

Innehåll

1 Introduction

1.1 Background

Nordpool, the Nordic electricity market, was founded in 1993 in Norway and named "Statnett Marked AS". On January 1 1996 the Swedish electricity market was deregulated and consequently incorporated with the Norwegian power market to create "Nord Pool ASA". Since then a number of countries have joined the market, including Denmark, Finland, the northern region of Germany and a bidding area in Estonia, making it "the largest market of its kind" (Nordpoolspot.com).

In recent years, criticism of the electricity market has been emerging. Some claim that for Sweden, the deregulation of the power market in 1996 (and hence Sweden's participation in Nord Pool) has been a driving factor of rising electricity prices and a non-efficient market for electricity. Some critique is aimed at the small number of large producers of electricity, possibly making the market oligopolistic in its form and, therefore, ineffective. This has been analyzed, among others by Hjalmarsson (Hjalmarsson, 2000). Others, such as the Swedish Energy Agency, point to the criticism of the pricing mechanisms of the energy market, claiming it to be inefficient (Statens energimyndighet, 2006). This paper will focus on the efficiency of the electricity market, since it is a less explored area in the case of Nord Pool than the literature regarding market competition and, therefore, might have new answers as to whether Nord Pool is a well-functioning market.

The efficient market hypothesis (EMH) is a way of theoretically illustrating at what degree a market is efficient. It defines market efficiency as how prices reflect information. In the original hypothesis, put forth by Eugene Fama (1970), there are three forms of efficiency; weak, semi-strong and strong. This paper will be focusing on the measure of weak efficiency. The weak form efficient market theory stipulates that all historical prices are incorporated in current prices. An implication of the efficient market theory is that if a market is inefficient it fails to price its product correctly since the information available is not fully incorporated in the price. It would also imply that buyers and sellers of electricity do not take all information into account when buying and selling on the market, making the pricing of electricity skewed. Another popular implication of the hypothesis is that if a market is inefficient, analyzing historical prices to realize excess returns becomes possible.

There are other drivers of price movements that more relate to microeconomic theory, such as what lies behind the supply and demand and political considerations. They are however not within the frame of this paper.

For the weak efficient hypothesis to hold, there are certain requirements to the historical prices of the nord pool electricity market (or any stock market) that must be fulfilled. Perhaps the most intuitive requirement is that price movements must be serially independent over time, meaning that future movements in the spot price do not depend on historical price movements. The unbiased future hypothesis will also be tested, which concerns whether future prices are unbiased predictors of future spot prices. Whether these requirements hold for the electricity market can be statistically tested. How to do this will be described further on in this study.

Is the Nordic electricity market efficient in its weak form and therefore well-functioning in terms of reflecting all historical prices in its current prices?

1.2 Purpose

The purpose of this study is to investigate whether or not the Nordic electricity market Nord Pool is weakly efficient within the context of the theoretical framework of the efficient market hypothesis. Additionally, the possibility of whether the market has evolved to become more efficient over time is explored.

By evaluating historic spot and futures price data from an econometric perspective I aim to bring some clarity to whether there is any viability in the claims of the electricity market being inefficient.

1.3 Delimitations

This paper aims to study the system price and futures price of the Nord Pool spot market. The frequency of the system price that will be analyzed is daily, weekly and monthly. The futures prices are weekly. The reason behind analyzing different sets of data with varying frequency is to see whether efficiency is more or less probable in a short frequency (i.e. daily prices) compared to an average longer-term price (weekly/monthly prices). The spot price data ranges from 1999-01-01 to 2011-09-30 and the futures data ranges from 2006-01-09 to 2010-04-30. The number of observations for each set of data is illustrated in table 1.

Table 1, Data set

Data Frequency	***Number of observations***
-Spot prices	
Monthly	153
Weekly	665
Daily	4656
-Futures prices	
Weekly	220

I use three different frequencies on the data to investigate if there is any difference in efficiency due to how often the price observation is made. It would make sense for more frequent data to be less efficient since it is often possible to observe arbitrage possibilities in small time spans due to the market not being able to adjust for small deviations in efficiency quickly enough.

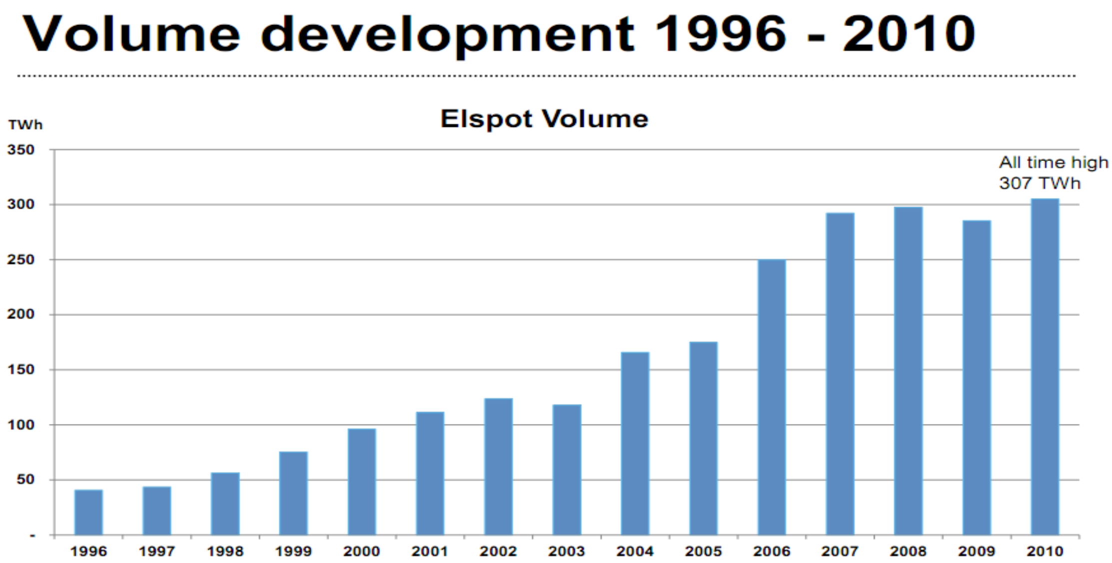
2. Theory

2.1 The Nord Pool electricity market

2.1.1 Background

Nord Pool is the largest electricity market in Europe, with both spot and futures trading. The financial market is handled by Nasdaq OMX commodities, as well as clearing services. Nord Pool Spot is jointly owned by the transmission operators in the Nordic countries. The spot market deals with physical delivery of electricity, whereas the financial futures market has no physical delivery. 74% of the total consumption of electricity in the Nordic countries is traded through the spot market, with a total volume of 307 TWh in 2010 (Nord pool pdf), compared to the total production in Sweden adding up to 145 TWh (Elåret 2010). Since its start of business in 1996 its trading volume has increased on a yearly basis as more countries and markets have been integrated in the market, with a couple of exceptions in 2002 and 2009 (Figure 2.1).

Figure 2.1, Total volumes traded in elspot 1996-2010 (Nord pool pdf)



The turnover in 2010 amounted to 18 billion €. In addition to the financial services, Nord Pool also publishes information from the independent power producers and consumers regarding future production plans and news that might come to affect the power price. More specifically, planned deviations in the production or consumption above 100 MW within a 6 week period needs to be communicated to the market. The same 100 MW limit applies to unplanned deviations. Given that market participants live up to these rules, it would imply that Nord Pool has the means to be efficient in terms of information that relates to price changes being easily attainable.

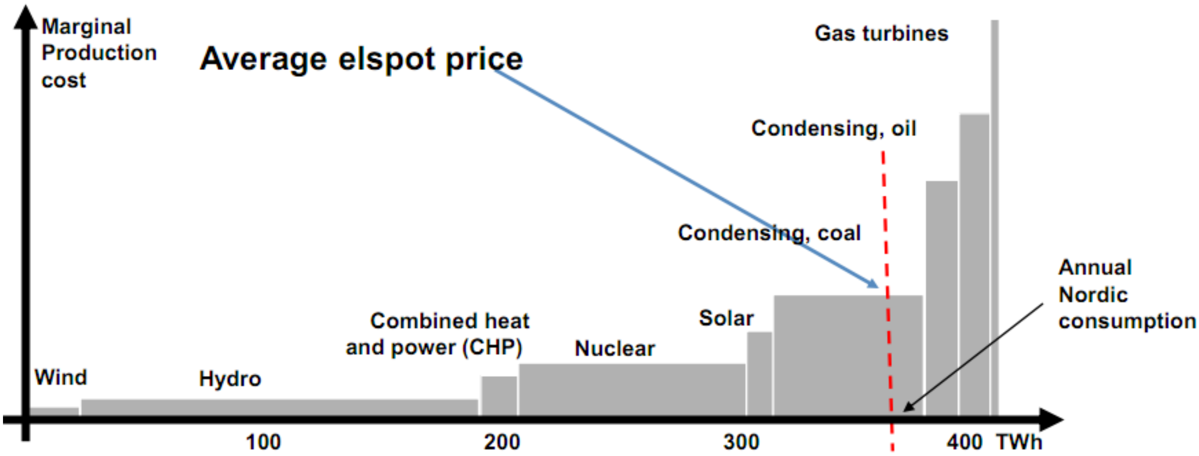
2.1.2 Determinants of system price

The Nord Pool system price is determined through demand and supply one day in advance. Since the prices are determined one day in advance, it is in actuality a day-ahead future price rather than an actual spot price. More specifically the demand curve is constructed through bids from parties interested in buying electricity. The total bids are aggregated to create a demand curve from highest price to lowest. Inversely, the producers/sellers state their offers from lowest to highest price to create a supply curve. When the supply and demand curves are combined, the system price is set as the price where the two curves intersect i.e. at the price where supply and demand quantity meets, see figure 2.2. This is equivalent to the equilibrium quantity and price in microeconomic theory, also called equilibrium or auction trading (Simonsen et al (2004)) .These aggregated curves are constructed for every hour of the day, giving hourly system prices.

Figure 2.2, System price formation

Further, this way of constructing equilibrium prices corresponds to microeconomic theory in terms of the marginal cost of electricity (the last unit of electricity produced to cover the aggregated demand) will equal the market price. This means that the system price corresponds to the most expensive means of production necessary to meet the demand, see figure 2.3.

Figure 2.3. Means of production and marginal cost. (Nord pool PDF)



The system price does not take bottle necks in the transmission grid into account. It is the price given that no such bottle necks are present. However, in the presence of such bottlenecks area prices are calculated in the same fashion as the system price. In order to conduct an overall analysis of the Nord Pool market the system price will be used.

2.2 Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) is concerned with information. More specifically, it is a hypothesis dealing with how information is incorporated and taken into account when pricing the instruments of a market. The extent and rate of speed at which a market adjusts to information has exceptionally important implications for how well a market functions and if the markets can be used for speculation through technical and fundamental analysis.

According to Fama (1970) a categorization into three different types of efficiency can be made to pinpoint how efficient a market is in terms of adjusting to and reflecting information; the weak, semi-strong and strong type of efficiency.

(1) **Weak market efficiency** is defined as a market that fully incorporates historical price movements in future ones. In more statistical phrasing that means that the returns (or price movements) must be serially independent of each other over time. If they are not, then one could derive future movements in price by looking at historical movements. In statistical terms, the weak market efficiency is often compared to the random walk model which states that future price movements cannot be predicted by historical price movements. Therefore, for a market to be weakly efficient, it needs to follow a random walk. This in turn leads to the conclusion that no excess returns can be made by analyzing past prices in a weakly efficient market. That means that given that a market is weakly efficient, technical analysis is to no use for an investor.

(2) Semi-strong market efficiency is, as the name implies, a more efficient type of market than the weak equivalence. In addition to having the properties of the weak market, the prices also reflect all public information. Fama takes annual reports as an example of publicly available information. Given that all this sort of public information is incorporated into prices, the market is said to be semi-strong. The implication for the investor is that there is no possibility to make excess returns by analyzing neither historical nor public information, implying that fundamental analysis would not be to any use when analyzing asset data.

(3) Strong market efficiency stipulates that prices reflect all information, including insider information. This logically implies that for a market to be strongly efficient, it also needs to be weak and semi-strong. The consequence for a strongly efficient market is that no excess returns can be made through superior information, since it is already incorporated into the price. The point is well illustrated by a story about a finance professor and a student coming across a $100 bill lying on the ground. The student reaches to pick it up, but the professor stops him and says, “Don’t bother, if it were a real $100 bill, it wouldn’t be there” (Malkiel (2003)).

In addition to what information is incorporated in the prices of a certain asset, there is also the question of how quickly the price adjusts to this information. Intuitively, one would suspect that there is a higher probability for inefficiency in the short-term if prices have not had the time to adjust to new available information. Therefore, different frequencies of data might provide different results. Tomek et al. (2007) comes to the same conclusion.

Empirically, the weak form of this model stands up well when tested on different markets. The original paper on these three degrees of efficiency referred to stock markets. Since then, a lot of work has been focusing on other types of markets. Since Nord Pool is a commodity market, this is the work most relevant to this paper. The literature on the specific topic of Nord Pool is not abundant, mostly because the electricity commodity markets are a relatively new concept. Before the introduction of these markets, electricity production and sales were closely regulated by the government.

2.3 Characteristics of Commodity Prices

There seems to be some general characteristics of prices in commodity markets that also apply on the Nord Pool prices. These characteristics are important to be aware of in order to correctly construct the econometric tests for the data series. The product being traded is produced at the same time as it is consumed. Does this property imply some special characteristics of the electricity market? Commodity prices are generally quite volatile (Deaton et al. (1992)). This applies to Nord Pool as well; it even seems to be more volatile than most other commodity markets (Byström, (2003)). This may be a consequence of the direct delivery. With no buffers in production and consumption, it is plausible that prices become more volatile. For example, if there is a disturbance in the supply (an abrupt stop in a large power plant) with the demand remaining and there is no “storage” of electricity to compensate for the lack of supply, prices will rise sharply. The same would be true for the inverse, a decline in the demand. Deng (200x..) reasons that because of the large share of hydropower being sold at Nord Pool, the reservoirs of water can even out the supply and demand shocks that cause the volatility (water reservoirs acting as storage), but it does not seem to be enough. The electricity market seems to be characterized by direct delivery. Furthermore, autocorrelation seems to be a prevalent characteristic in the commodity markets (Tomek et al).

Commodity prices also differ from stock markets in that it often depends a lot on weather conditions (Deaton). Seasonality effects seem to be empirically present in the time series data when it comes to commodity prices (Wang, Tomek). However, these are uncommon to deal with in the literature according to the same authors. One solution would be dummy variables for seasonalities. Byström deduces seasonality in his analysis of Nord Pool; Spot prices seem to be higher on week days, higher during the day than the night and higher during the winter than the summer. The reasons for these seasonalities are quite intuitive. Since prices are governed by supply and demand, they react to higher demand from the busiest industry hours. That explains why prices are higher during the day and week days. The yearly seasonality stems from electricity being in higher demand when it is colder outside, a consequence of houses needing to be heated etc. (Simonsen, p.7).

Gjölberg (2010) suggests that there should be a reason for producers and consumers to capitalize on these seasonal patterns and questions why this is not being done by moving consumption or production of electricity. In theory, such a question is rightfully posed. There are, however, a number of practical reasons why it would be hard to move production and consumption. For instance, moving consumption from a Friday to a Sunday for a business that relies heavily on the use of electricity inflicts a number of other costs such as higher payment for labor.

Similarly, moving production from one day to another is costly in terms of having to shut plants on and off to meet the peak hours of prices. Furthermore, it would not be beneficial in terms of public opinion if the power companies opted to shut down their plants in less profitable hours or days of the week and turn them on when prices are at its' highest. These problems to maximize on arbitrage opportunities could be described as a sort of transaction cost that negates the above mentioned opportunities of arbitrage.

Fama (1970) discusses transaction costs as a vessel that might hinder the presence of efficiency in the markets. That is, if information is costly to come by, then information will not be obtained by the market participants and, consequently, the market will not reflect all available information. However, information regarding seasonal patterns in power prices is easily obtained and should not be a problem in the way Fama described transaction costs being an obstacle.

However, the question remains; are these seasonal patterns in themselves causing the spot prices on Nord Pool to be predicatble and therefore causing the market to be inefficient? This might at least be an indication that it is indeed inefficient.

When testing for stationarity using the Phillips-Perron test, Byström finds that his time series of logarithmic spot prices are stationary. His reasoning behind this result is that his data series (1996-1999) is too short to conclusively rule out non-stationarity in the long run. One might also consider that Byströms time series is from the first years of operation of Nord Pool, which might affect its efficiency. Since then, the market has grown larger (both geographically and in terms of market participants) and more liquid which should imply the possibility that it is now more efficient. For that reason this paper will, beyond testing the whole time series of spot price, also test the future spot parity for the latter years (2006 – 2010) to see whether a shift has occurred.

2.4 Futures and efficient market hypothesis

The efficient market hypothesis also applies to the relationship between future and spot prices. As mentioned above, for a market to be efficient there cannot be any arbitrage opportunities. This gives rise to a certain relationship between the futures price at a certain time and the subsequent spot price at delivery of the future;

$$F_{t(t-k)} = E(S_t) + P_t$$

The interpretation of the above relationship is that the futures price today should reflect the expected future spot price plus a “premium”, which can be interpreted as storage costs of the commodity. The expected spot price is a rational, efficient forecast, conditional on all information available at time *t-k* (Fama, 1984). This relationship is dependent on the assumption of no arbitrage possibilities (= efficient market). So to test this assumption, a number of regressions will be performed to see whether the future spot parity holds for Nord Pool.

As previously stated, if spot prices are efficient, they follow a random walk since information is reflected in the prices as it emerges. Extending this reasoning to the relationship between the futures and spot price, it means that forecasting spot prices through futures prices should be unbiased.

I.e. the futures prices, regressed on the spot prices in the week of delivery, should hold some explanatory power (Eq 11). Further, a change in the spot price between the time periods of when the future was bought and when it was delivered should be able to be explained by the difference of the futures and spot price at the time of initial purchase (Eq 12). If this does not hold true, meaning this can be modeled, there is a theoretical possibility of arbitrage since this analysis could be done by individuals and institutions. I.e. if it can be shown that future prices holds no, or low, relationship to the spot price, then it is an indication of lack of efficiency in the market.

This theory assumes that the commodity is storable. Following the reasoning of Gjölberg (2001), the producers of electricity have that possibility through hydro reservoirs. The reservoirs serve as an implicit way of storing electricity in the sense that the producers can choose to fill the hydro reservoirs (i.e. store electricity) as opposed to producing at any given time.

Keynes and Hicks posed a theory stating that if hedgers go long (short) in the futures market and speculators go short (long), the futures price will be higher (lower) than the expected spot price. This relationship occurs because speculators want compensation for their risk taking, while hedgers are prepared to pay for the security they get in hedging (Hull, 2006).

2.5 Statistical theory

2.5.1 Testing for stationarity in a time series

The reason a stationarity test is applicable when evaluating the efficient market theory is because it is a measure on how data from different points in time depend on each other. More specifically, the weak market efficiency theory stipulates that for a market to be weakly efficient, future prices cannot be predicted through analysis of historical prices. This is analogous to the rationale behind testing for whether or not a time series is stationary. For a time series to be stationary there are three conditions that must be fulfilled – the **(1)** mean, **(2)** variance and **(3)** covariance of the time series must be independent of time, i.e. constant (hill/Griffiths p.336).

To illustrate the reasoning behind the concept of stationarity, the example of a random walk can be used. Consider;

$$y_t = py_{t-1} + \varepsilon_t \tag{1}$$

Where **y** is a time series that depends on **t** (time) and **ε** is a random disturbance term with 0 mean and a constant variance. If the **p**-coefficient is 1 or larger, the time series is said to be non-stationary.

Given that **p** = 1, the equation becomes;

$$y_t = y_{t-1} + \varepsilon_t \tag{2}$$

Assuming that the first observation in the time series is $y_0 = 0$, then

$$y_1 = 0 + \varepsilon_1 = \varepsilon_1. \tag{3}$$

In extension, this means that the time series **y** depends solely on the random disturbance term .In numerical terms it can be expressed as;

$$y_t = \sum_{n=1}^{t} \varepsilon_n \tag{4}$$

This also means that the variance of the time series depends on time, since the variance of **y** will be the variance of the random disturbance term multiplied by time (Undergraduate economics, hill/griffiths, 16.1 stationary time series). So for cases of **p** being equal to 1 or larger, the time series will be non-stationary since it violates the rule of a constant variance over time.

What this illustrates is that the non-stationary random walk, the time series **y,** depends solely on the stochastic disturbance term. The implication of this result is that if someone were to look at the value of y_t at time t, there would be no way to predict what the value for y_{t+1} would be, since the difference between the two points in the data series is solely dependent on a random variable. Therefore the time series is non-stationary.

Hence, the application for testing a time series of spot prices to find out whether it is stationary or not makes sense if the aim is to find out whether or not historical prices have any bearing on future prices in terms of predicting them through econometric regression and inference.

2.5.3 Autocorrelation and autoregressive order

Autocorrelation in a time series implies that there is a relationship between the residuals. It can be explained as the covariance between a variable and itself at two different points in time. For example, if a pattern of changes in the time series can be found, so called "runs" of positive or negative changes, it is said to be autocorrelated.

Time series regression often suffers from the problem that its residuals are autocorrelated (hill/Griffiths, p.258) and even more so with commodity price series (Deaton et al., 1992). When performing Ordinary Least Squares (OLS) regression one of the underlying assumptions is that autocorrelation is not present in the time series. Therefore, the consequence of ignoring autocorrelated residuals is that regressions become spurious and, therefore, lose its explanatory power. There are several tests used for detecting autocorrelation, one of the more frequent ones being the Durbin Watson test which is applicable when dealing with a time series that is autoregressive of the first order. For higher orders of autoregression, the Breusch-Godfrey serial LM test will be used to interpret the data. Testing for autocorrelation needs to be performed twice; firstly to be able to model the data to account for (possible) autocorrelation and secondly to make sure that the stated model has been able to efficiently remove autocorrelation from the model.

Determining the autoregressive order of the data series is fundamental to be able to perform correctly defined tests for autocorrelation and stationarity. Both the Augmented Dickey-Fuller and the autocorrelation tests need a defined order of autoregression to be able to produce non-biased results.

The literature on stationarity and modeling autoregressive series seem to favor two different tests on how to determine AR(p)-order[1].

Firstly, "information criterions", such as the Akaike information criterion (AIC), has another methodology of measuring AR(P)-order. It is useful when comparing models to determine

[1] The AR(p)-order refers to the order p of autoregression. I.e. a time series of autoregressive order p = 5 calls for an AR(5)-model.

which model fits best to the data set (Akaike, 1974). According to Liew (2004), not only does the best estimator depend on the sample size, but the tests themselves become more accurate as the sample size increases. For the daily data the sample size should not be an issue as it has over 4000 observations. For the other two frequencies of data, it is, however, worth noting that an under-estimation of AR-order might occur, since the observations are more sparing in quantity.

The second way of obtaining the AR(P)-order for the model is the general-to-specific approach, suggested among others by Dolado et al. It is a practical approach in which the model is estimated with a stated maximum number of lags, and then decreasing the lags until the last lag is statistically significant using t-statistics. The maximum number of lags will be determined using the Schwert criterion.

2.6 Previous Studies

As mentioned earlier, studies of efficiency of Nord Pool are relatively scarce. This will be a presentation of the ones that have been performed and also similar tests on other electricity and commodity markets.

Hjalmarsson (2000) conducted the ADF stationarity test for several variables, including weekly system prices, for the period 1996 – 1999 and adjusted for seasonality. He found that, during this period, the system price was non-stationary. Bask et al (2009) analyzed the market using a similar approach as Hjalmarsson. Their time span was longer, stretching from 1996 to 2004. Their results support stationarity in the system price. Byström investigates daily system prices over roughly the same time span and finds evidence contrary to Hjalmarsson, that system prices are stationary using the Phillips-Perron stationarity test. This may be due to specification of the tests and also the frequency of the data. As mentioned, one might suspect that higher frequency data is more prone to be stationary. Arciniegas et al (2003) assess the efficiency of the North-American electricity markets on an hourly basis. Their results are varying. The Californian market seems less efficient than the corresponding New York market. Their reasoning behind the results is that the Californian market relied heavier on the forward market, resulting in a smaller volume being traded in the spot market and thus resulting in inefficiencies.

Efficiency measured through future-spot relationships on Nord Pool has been investigated by Gjölberg et al (2001). They tested 4-week and 12-week future prices against spot prices to see whether the future prices were unbiased predictors of subsequent spot prices and therefore efficient. The time period tested was between 1996 and 2001. After concluding that the futures prices were bad predictors, they included some additional terms representing the level of information and concluded that there was a lack of efficiency in the market.

Chinn et al. (2005) constructed similar tests on different types of commodities (crude oil, natural gas etc.) in the US. They found that for most of those types of commodities the futures were unbiased predictors of spot prices, they were however bad at predicting future movements of the commodity prices. The results should be handled with care in comparison to what the results in this paper might show, since there are some characteristics that differ in an electricity market (such as storability) compared to the commodity markets analyzed by Chinn et al that might affect the results.

3. Method

This study is quantitative in its character and the analysis is performed on historical price data received from the Nord Pool spot database and Nasdaq OMX commodities FTP server. The tool of analysis is statistic inference based on economic theories. The statistical approaches are widely used and have been rigorously tested. The main test measurements are the Augmented Dickey-Fuller test for unit roots and OLS regression.

3.1 Data set

The data is comprised of a) three different time series of the same variable, the system price of electricity and b) the 6-week futures price with the system price as the reference price. The difference between the spot price time series is the frequency of the data. All three spot series cover nearly 13 years of system prices, from 1999 to September 2011, while the futures prices cover 4 ½ years between 2006 and 2010.

3.2 Calculations

3.2.1 Determining AR(P)-order

Akaike Information Criterion

$$AIC = (-2)\log(maximum\ likelihood) + 2(number\ of\ independently\ adjusted\ parameters\ within\ the\ model) \quad (5)$$

The testing procedure is defining the candidate models and then comparing the AIC values, with the lowest value being the “best” model in terms information fit.

General-to-specific method and the Schwert criterion

The general-to-specific method of determining the number of lags to include in the model consists of two steps; first decide on a maximum lag length. Second, reduce the lag length one by one until the last lag is statistically significant. Schwert (1989) has suggested a formula based on the number of observations to determine what maximum lag one should start out with;

$$Maxlag = 12 * \left(\frac{N}{100}\right)^{1/4} \quad (6)$$

3.2.2 Detecting autocorrelation

As previously mentioned, a cause for concern when testing for stationarity is the possible presence of autocorrelation in the residuals. Hence, a measure of autocorrelation must be included in our tests to make sure that the regressions are not spurious. A generally accepted test when using OLS regression is the Durbin Watson test. The test statistic is;

$$d = \frac{\sum_{t=2}^{T}(e_t - e_{t-2})^2}{\sum_{t=1}^{T} e_t^{\,2}} \quad (7)$$

Where $\boldsymbol{e_t}$ are the residuals at time t and **T** is the sample size.

It is, however, only applicable for testing autocorrelation of the first order. For higher orders of autoregression, the Breusch-Godfrey test is more accurate. The null hypothesis of a Breusch-Godfrey LM test is that there is no autocorrelation.

The order of autoregression will follow from the above mentioned AIC and general-to-specific tests to see which method to employ in determining the presence of autocorrelation.

3.2.3 Testing for stationarity (Augmented Dickey-Fuller test)

The Augmented Dickey-Fuller test is an extension of the more simplistic Dickey-Fuller test. It allows for a time series to be autoregressive in an order higher than one. If a time series is autoregressive of an order > 1, the residuals of a random walk shown in the theory section above will be autocorrelated and using a standard Dickey-Fuller test would lead to a spurious regression. To adjust for that, the ADF test includes a number of lags in the regression to neutralize the risk of autocorrelation. In addition, there are three different regressions to choose from; X.**1)** ADF with no constant or trend X.**2)** ADF with constant and no trend X.**3)** ADF with constant and trend. The three different test equations are illustrated below.

$$\Delta y_t = p y_{t-1} + \mu_n \Delta y_{t-1} \pm \cdots + \mu_{n-1} \Delta y_{t-n+1} + \varepsilon_t \quad (8)$$

$$\Delta y_t = \alpha + p y_{t-1} + \mu_n \Delta y_{t-1} \pm \cdots + \mu_{n-1} \Delta y_{t-n+1} + \varepsilon_t \quad (9)$$

$$\Delta y_t = \alpha + \beta t + p y_{t-1} + \mu_n \Delta y_{t-1} \pm \cdots + \mu_{n-1} \Delta y_{t-n+1} + \varepsilon_t \quad (10)$$

Where **α** represents a constant, **β** the trend coefficient that depends on time, **n** is the lag order and **μ** is the coefficient in front of the lagged differences that makes the ADF test differ from the standard DF test.

The null hypothesis is;

$$H_0: p = 0 \ (non - stationary)$$

And consequently the alternative hypothesis;

$$H_1\colon p < 0\ (stationary)$$

To perform the test, Ordinary Least Squares (OLS) regression is used. Including a constant in the ADF-test is appropriate when the time series is suspected of having a mean separate from 0 (harris/sollis, p44). In the case of the spot prices a reasonable assumption would be that the mean spot price is differed from 0. Hence, including a drift when calculating the regressions ought to increase the reliability of the test. Additionally, one of the concerns of this paper is that prices have risen since the inauguration of Nord Pool so there might also be a trend in the time series. Therefore, a specification with both a constant and a trend will also be tested. It is, however, worth noting that the power of the test is lowered for every additional term I include in the test (Wang, Tomek).

The usual approach would be to look at the t-statistic of such a regression to draw the inference. In the case of the ADF-test this is not possible since it would lead to an over-rejection of the null hypothesis of non-stationarity (harris/sollis, p43). Instead a specially constructed distribution, called the tau distribution, is used.

3.2.4 Future and spot price relationship

OLS is used to test the relationship between futures and spot prices. The two regressions I will use to test for bias is;

$$S_t = \beta_0 + \beta_1 F_{t(t-k)} + e_t \tag{11}$$

$$S_t - S_{t-k} = \beta_0 + B_1(F_{t(t-k)} - S_{t-k}) + e_t \tag{12}$$

Where $F_{t(t-k)}$ is the futures price on the first day of trading (6 weeks before the closing date), S_t is the spot price during the week of delivery (reference price for the futures contract) and S_{t-k} is the spot price in the same time period as the first day of trading futures price.

If the futures price is an unbiased predictor of the spot price (and therefore negates arbitrage possibilities), B_1 will not be significantly different from unity in Eq. 12 and 13.

4. Results & Analysis

4.1 Spot price stationarity

The figures below are the plotted spot prices for the three different frequencies. As can be expected, the daily spot prices exhibit higher variation than the weekly and monthly data, as seen in the variance (Table 4.1). The mean spot price differs from zero, meaning that a constant should be included in the ADF test.

Table 4.1, Descriptive statistics

	Daily	Weekly	Monthly
Mean	32,86	32,86	32,88
Median	30,07	30,28	29,6
Std. Dev	16,18	15,9	15,5

Figure 4.1, Daily spot prices, €.

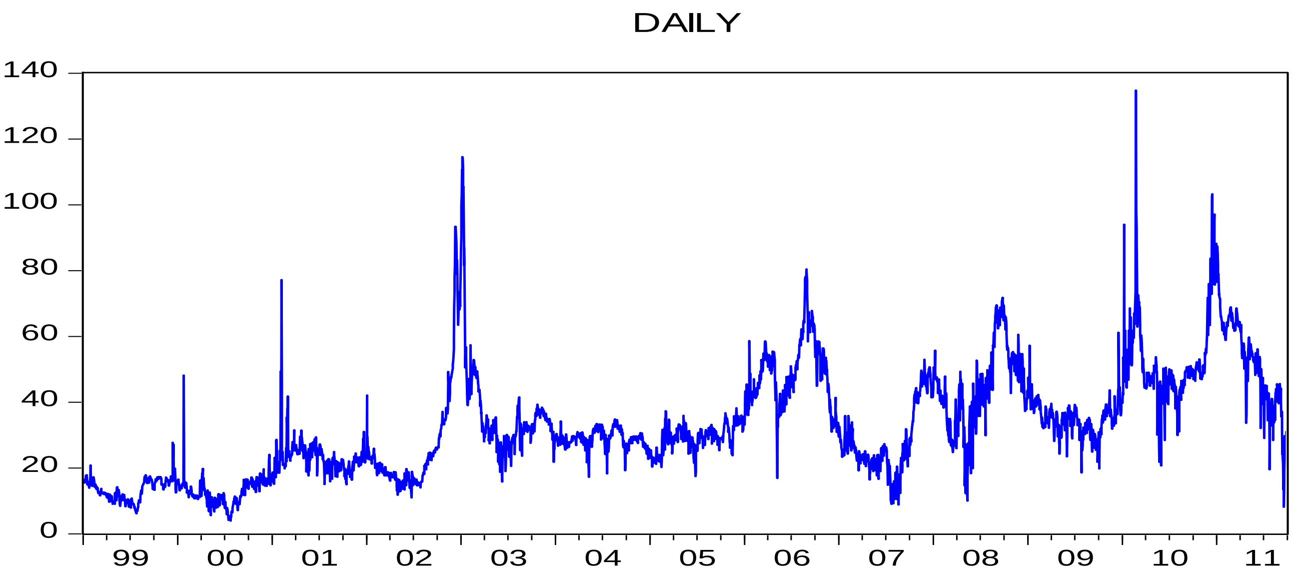


Figure 4.2, Monthly spot prices, €.

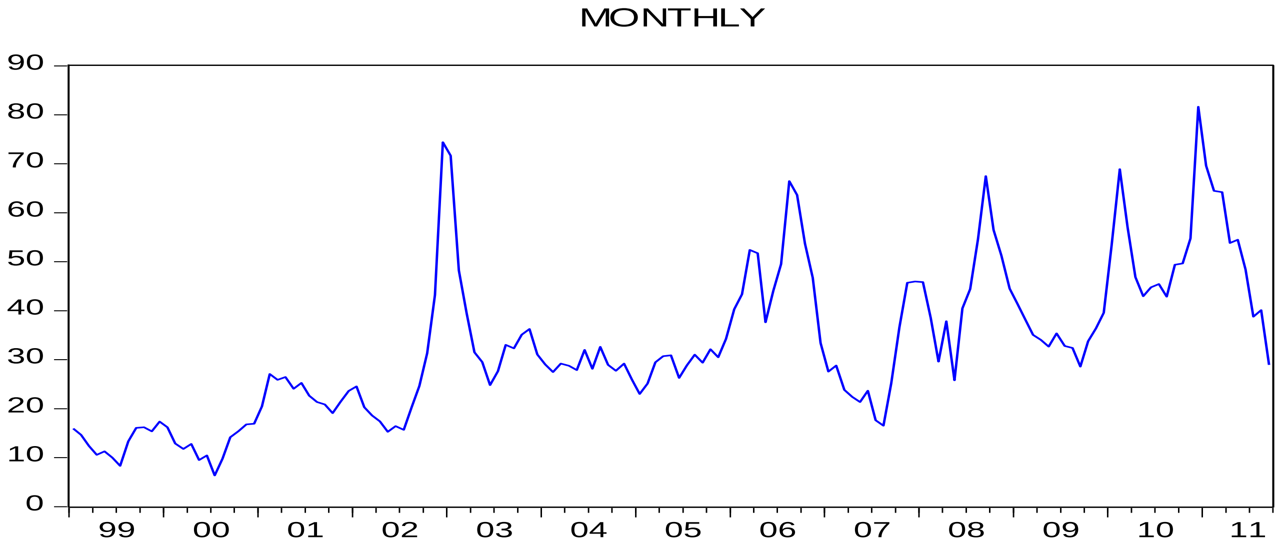


Figure 4.3, Weekly spot prices, €.

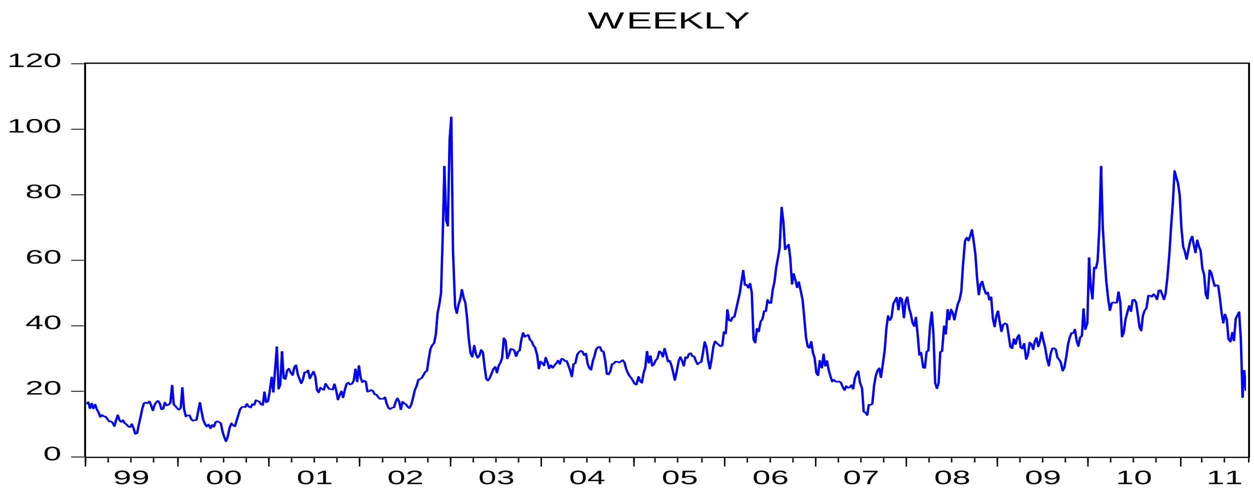


Table 4.2 shows the number of lags determined through the Schwert criterion. The maximum lags are highest for the daily time series and lowest for the monthly series, which follows from the calculation that depends on the number of observations.

Table 4.2, Maximum lags for different frequencies

Schwert maximum lags	
Daily	31
Weekly	19
Monthly	13

Using the AIC and the General – to – specific methods to determine lag length in the ADF tests, the results of these ADF-tests are depicted in table 4.3. At the 10% level of significance, all frequencies of spot prices are stationary. Using 5% significance the monthly spot prices are non-stationary, while the weekly and daily prices remain stationary. It would seem that the spot prices are “more stationary” the higher frequency of data points.

The determined lag orders are highest in the daily time series, meaning that the maximum number of lags determined through the Schwert criterion is being utilized.

Table 4.3, ADF test results (Mackinnon critical and p-values)*

ADF TESTS USING AIC AND GENERAL-TO-SPECIFIC LAG DETERMINATION

	#Lags	Sample Size	Tau-statistic	P-value
Daily				
- AIC	30	4625	-3,751936***	0,00348
- Gen-to-Spec	31	4624	-3,685245***	0,00438
Weekly				
- AIC	5	659	-3,282933**	0,01608
- Gen-to-Spec	10	654	-3,62491***	0,00555
Monthly				
- AIC	6	146	-2,619873*	0,09127
- Gen-to-Spec	6	146	-2,619873*	0,09127

***	Significant rejection of null at 1%
**	Significant rejection of null at 5%
*	Significant rejection of null at 10%

The regressions also show no serial correlation since we cannot reject the null of no serial correlation at any level of significance below 10%. As can be seen by table 4.4 of the test statistics for the Breusch-Godfrey autocorrelation test;

Table 4.4 Serial Correlation test

Breusch-Godfrey serial LM test for autocorrelation		
	Test Statistic	P-value
Daily		
- *F-stat*	1,722496	0,1787
- *Obs*R-squared*	3,467903	0,1766
Weekly		
- *F-stat*	0,168369	0,8451
- *Obs*R-squared*	0,343924	0,842
Monthly		
- *F-stat*	0,047968	0,9532
- *Obs*R-squared*	0,102918	0,9498

4.2 Future spot bias

The mean difference in the 6-week futures price and the spot price in delivery week[2] is 2,24 €, or measured as a percentage of the spot price the futures price is on average 9,9% higher than the subsequent spot price.

Below are the results from regression (12) and (13). In both regressions the β_1-coefficient is significantly different from unity, suggesting that the efficient market hypothesis does not hold up, as the basis (future price – spot price) does not hold explanatory power over the spot price. When looking at the adjusted R^2, it can be seen that the futures price six weeks ahead explains about 45% of the subsequent spot price for the first regression and decreases significantly for the second regression, meaning that about 2,8% of the variation in the changes of the spot price is explained by the future-spot basis. The Durbin-Watson statistic implies the presence of autocorrelation which in line with the methodology of Gjölberg is acceptable.

[2] $F_{t(t-6)} - S_t$

	β(0)	β(1)	SE(β(1))	T-stat (β)	DW	Adj. R2
Eq. (11)	11.18581	0,685244	2,279917	4,906237	0,285335	0,449369
Eq. (12)	-0,42427	0,226212	0,083959	2,694331	0,386205	0,027788

These results are in line with the previous findings of stationarity in the spot prices, pointing to the possibility that Nord Pool is indeed an inefficient market in the definition by Fama.

5. Conclusions and further studies

5.1 Conclusions

This paper set out to investigate whether or not the Nordic electricity market was efficient in the economic sense, defined by Eugene Fama. First through an analysis of the spot prices at different frequencies and second through future spot parity.

The results seem to point to inefficiencies in both cases. The daily and weekly quoted spot prices seem to be stationary, whereas the monthly averages are non-stationary. This could be a confirmation of the notion that short-frequency data is prone to be less efficient whereas long-term (monthly) average prices are more efficient in adjusting for information.

What could be the possible explanations for inefficiency? Some previous studies point to the relative youth of the market, that it is not yet developed. However, these claims are harder to legitimize now, since those studies use data older than this study. Nord Pool in its present form has developed into the largest exchange for electricity in the world with a large number of participants. Therefore, lack of liquidity does not seem to be a satisfactory explanation.

Transaction costs, as described in an earlier section, are also a possible explanation. If information is hard or costly to come by, it might be pricier to obtain information than the possible gains it would lead to. This also seems as an unsatisfactory explanation. With the system of sharing information on production and consumption deviations ahead of time that might affect the prices, there seems to be little or no cost to obtaining information relevant to pricing. The seasonality property of the market is also well-known and should not be a factor in the lack of efficiency.

The future spot parity deviations might give a more plausible explanation. As mentioned, a large share of electricity production on Nord Pool consists of hydro power. This is also the reason that the future spot parity should hold, since it demands that the commodity in question can be stored. However, it is only storable for the producers (through water reservoirs). What does that imply? A possible consequence is that producers are less inclined to use the futures market than consumers. Since the consumers cannot store electricity physically without extremely large costs, they need to resort to store it "artificially" through futures contracts. This is in part confirmed by the fact that the futures price is about 10% higher than the resulting spot price, keeping in mind the theory of Keynes and Hicks who said that this relationship occurs when hedgers go long in the futures market. It also suggests that the producer side of the market has a better position to take advantage of arbitrage opportunities, since they can utilize their storage capabilities. This might be a cause of the inefficiency that can be observed. It can be related to the discussion on transaction costs. If the cost of storage for consumers is higher than the potential gains in an arbitrage strategy, then that strategy will not be implemented and inefficiencies will not be arbitraged away.

5.2 Further studies

This study has shown that Nord Pool quite possibly suffers from informational inefficiencies in both the spot prices and in the relationship between spot and futures prices. The most useful implication of an inefficient market is to take advantage of the possibilities such a market implies. A further study could implement the results in this paper to empirically test for excess returns using different arbitrage strategies.

The importance of hydro reservoirs and how it might have some possible explanatory power regarding the observed inefficiencies has also been mentioned in this study. The relationship between reservoir levels and price movements has been studied by Gjölberg to a certain extent, but has not been implemented in the context of profitable trading strategies.

Furthermore, there are several other approaches for measuring the presence of stationarity that could be investigated, for example the seasonality properties of the time series or more advanced time series models could be taken into account to verify (or discard) the results in this paper.

6. References

6.1 Primary Data

Nord Pool Spot price database

http://www.nordpoolspot.com/Market-data1/

Nord Pool FTP Database

ftp://ftp.nordpool.com/

6.2 Secondary Data

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