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Master Thesis

An analysis of energy prices and market efficiency at Nord Pool

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I. Abstract

The main objective of this thesis consists of two parts, an analysis of special characteristics of electricity prices at Nord pool and an assessment of how market efficiency[1] has changed as the market matured.

The analysis revealed that the electricity prices have idiosyncrasies not found in other commodities. The non-storability of electricity is one of the major causes for this. Nord Pool's market supply is highly represented by hydro electricity producers. This makes it easy for suppliers to adjust their production to shifting electricity prices. The demand side does not have this freedom, which gives market power to the supply side.

The fundamentals of electricity give the prices a natural pattern within a day, week and year. The prices also exhibit large fluctuations and price spikes due to demand moving different power generating assets in and out of the market. Higher levels of demand bring assets on the upper, steeper portion of the supply curve in to production (i.e. assets with higher marginal production cost). Small changes in demand at this level will result in high price variations. An increase in the general demand without any major addition in production may cause a lasting shift in the demand curve to a steeper part of the supply curve and may be one factor to explain the higher and more volatile prices observed in the electricity market after 2005.

Forward prices have seemingly the same characteristics as the spot prices, represented by the high correlation coefficient of over 95%. However, the relationship between spot and forward prices gives valuable information in assessing how the market prices the forward contracts.

Efficiency in a market is influenced by the number of market participants and the liquidity in the market. Both have increased considerably since the opening of Nord Pool, and one could expect the efficiency to increase as the marked matured. However, the results from this analysis showed that it was only an increase in the 1 week contract. The other contracts in the analysis (2-6 weeks contracts) did not show an increase in efficiency. An extended analysis based on contracts with longer delivery periods (month, quarter, year) would be of interest. It may show better market efficiency improvement, since liquidity has increased for these contacts.

[1] An efficient market is one where information is rapidly disseminated and reflected in prices.

II. Acknowledements

This thesis is written as a part of the Master of Science in Economics and Business Administration program at the Norwegian School of Economics and Business Administration (NHH). The master thesis is written in conjunction with my major in Financial Economics.

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Further, I would like to thank Viz Risk Management for giving me access to their FTP server. Additionally, I would like to thank Inger Øydis Storebø and Lene Portocarrero for useful comments and suggestions. A special thanks also go to Jon Magnar Storebø for helping me with various macros made in conjunction with this thesis, for helpful advice and for his encouragement through-out the process.

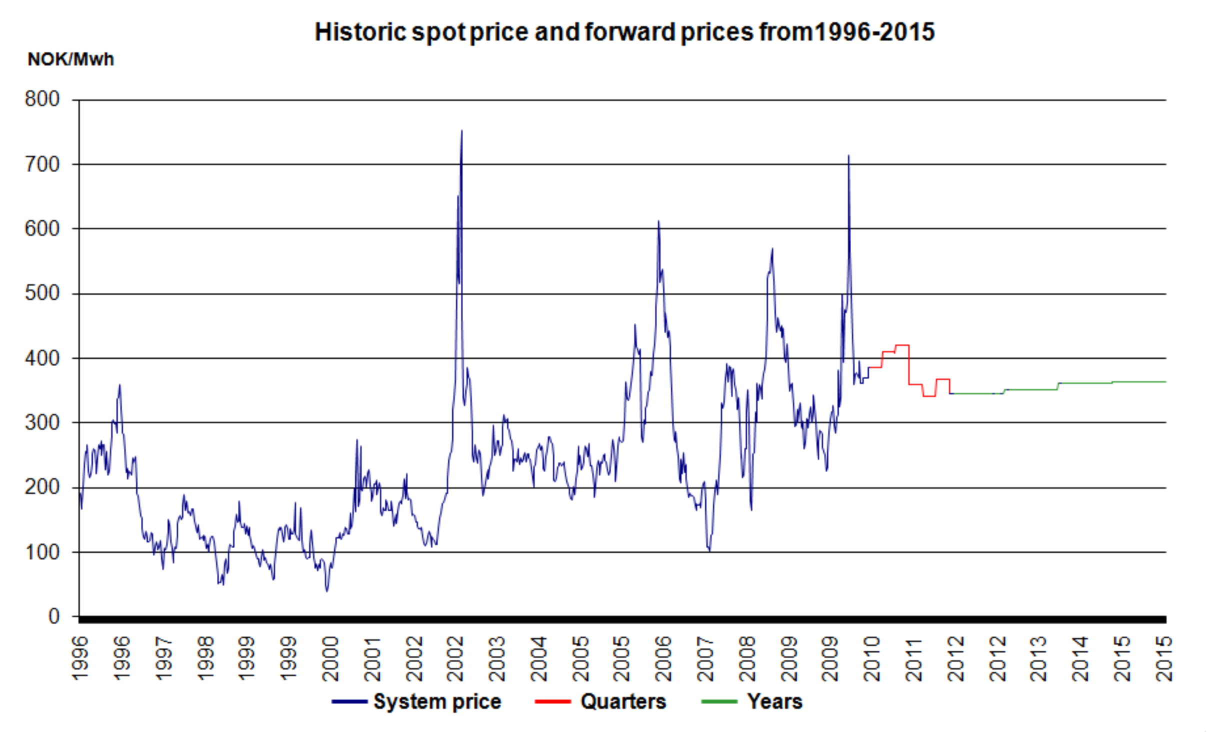
III. Table of content

1. Introduction

Nord Pool is a power exchange that is a consequence of the liberalization of the Nordic electricity market. It was unique of its kind when it opened in 1995 as the world's first multinational power exchange. The good liquidity and stability of the exchange has made it a popular object for analyses and research projects. Although the market is stated to have many good qualities and is used as an example for other power exchanges that have emerged all over the world, many academics have found that the market is inefficient[2].

An assessment of the market dynamics and history can be a good introduction to the electricity market fundamentals. In order to asses this there are many variables one can investigate, prices, volumes, exogenous variables, etc, but the most descriptive is probably prices. Graph 1 provides an overview of the historical spot prices, and forward prices for contracts traded on 30 April 2010.

Graph 1 Nord Pool prices[3]



[2] Ref: Gjolberg and Johnsen (2001) Herra´iz and Monroy (2009).
[3] Source: Nord Pool ftp server base date 30.04.2010 Simplification of the forward curve used the exchange rate 30.04.10 to turn every forward to NOK, for a more correct approach one should incorporated a currency forward curve as well. All prices are in nominal terms

Graph 1 reveals that the spot price has fluctuated greatly since the exchange opened. It is apparent that the market is dynamic and obviously changing over time. In the infancy state of the exchange there were relatively stable patterns (seasonal variation) followed by a substantial temporary price increase in the winter of 2002/2003. After this shock there was a relatively stable period. In 2005 there seems to be a shift in the time series to higher and more volatile prices. Which raises the main question in this thesis;

Have the apparent shift in the price mechanism after 2005 been a result of improved market efficiency, or is it a consequence of shifting market conditions?

The thesis starts with an analysis of electricity price characteristics at Nord Pool, whereas this is finalized in an empirical analysis of market efficiency. The objective of the empirical analysis is not to propose formal models of price mechanism in the market, but rather to use descriptive statistics and simple regression analysis to investigate to what extent easy observable variables can contribute to explain the historical observed market efficiency at Nord pool, and how it has changed as the market has matured.

Market efficiency is a well founded measure of how market participants incorporate information in their pricing estimates. The term has some controversies when applied in the real world. However, for a market to benefit from the positive economics aspects of free markets there has to be some confidence in the market and the pricing mechanism. So high market efficiency would probably be prosperous for the market as a whole.

An introduction to the Nordic electricity market and the products sold at Nord Pool, are presented in chapter 2 before presenting the data used in the analysis in chapter 3. In chapter 4 there will be a review of price determination in the electricity sector before chapter 5 summarizes this with observed statistical properties of the electricity prices. Chapter 6 looks closer at how forward prices are determined and how the spot and forward prices have historically interacted with each other at Nord Pool. Chapter 7 takes a deeper look into market efficiency and problems one can encounter when assessing market efficiency. The model framework is presented in chapter 8, before the results of the analysis are presented in chapter 9.

2. The Nordic electricity market

Since the early nineties many countries have started the process of deregulation of their energy sectors. The speed and scope of the reforms vary greatly across countries, but the main purpose for them all is to open the energy market for competition to secure a more efficient and cost effective energy production.

Deregulation in the Nordic area started with Norway's Electricity Act of 1989. This legislation was the basis that created the first open electricity market which opened in January 1993. In January 1996, Nord Pool was created when Sweden joined. It was the world's first multinational electricity market. The other Nordic countries joined this market as their government issued similar restructuring; Finland in 1998, West Denmark in 1999 and East Denmark in 2000. The German area KONTEK joined the market in 2005 and Estonia was included in April 2010[4].

There are four independent divisions within the Nord Pool organization; 1) Nord Pool ASA (the Exchange for financial derivatives and carbon products), 2) Nord Pool Spot AS (Spot market for Nordic day-ahead power (Elspot) and continuously trading (Elbas)), 3) Nord Pool Consulting AS and 4) Nord Pool Clearing ASA. The ownership of the exchange has undergone some major changes the last couple of years. In 2008 Nasdaq OMX Commodities AS bought Nord Pool consulting AS and Nord Pool Clearing AS. The sellers (Norwegian Statnett and the Swedish Svenska Kraftnät) imbedded a put option on Nord Pool ASA. In March 2010, Statnett and Svenska Kraftnät decided to exercise the option and the sale is currently under approval from the Ministry of Finance in Norway. The sale does not include Nord Pool Spot AS which is owned by the major grid companies of the Nordic area[5].

The Nord Pool ASA´s[6] primary market can be divided into three; a "physical market" (Elspot and Elbas), a "financial market" and a market for carbon emission (EUA and CER).These markets are discussed in detail in chapter 2.1 – 2.3.

[4] Despite the fact that Nord Pool contains area outside the Nordic region will it in this paper be addressed as the Nordic area
[5] Statnett(NO, 30%),Svenska Kraftnat(SE, 30%) Fingrid(FI, 20%) and Snerginet (DK, 20%)
[6] Called Noord Pool in the remaining document

The success of Nord Pool can to some extent be given to the variety of energy production resources in the Nordic countries, see Table 1. This characteristic gives the market a possibility to diversify its dependency on different types of resources throughout the day and year. As can be seen from the table, Norway mainly produces energy from hydropower in contrast to Denmark which is primarily driven by coal and natural gas, and Sweden by nuclear power generation.

Table 1 Energy production Nordic contries, owerview 2008 [7]

		Nordic	Denmark	Finland	Norway	Sweden
Population	mill.	**24,9**	5,5	5,3	4,8	9,3
Total consumption	TWh	**396,1**	36,1	87,0	128,9	144,1
Maximum load	GW	**59,3**	6,1	12,5	18,4	22,2
Electricity generation	TWh	**397,5**	34,6	74,1	142,7	146,0
Breakdown of electricity generation						
Hydropower	%	42	0	23	98	47
Nuclear Power	%	18	-	30	-	42
Other thermal power	%	35	80	47	1	10
Wind power	%	5	20	0	1	1

More on this topic will be discussed when characteristics of electricity prices are reviewed in chapter 4. In the following the different markets will be described closer.

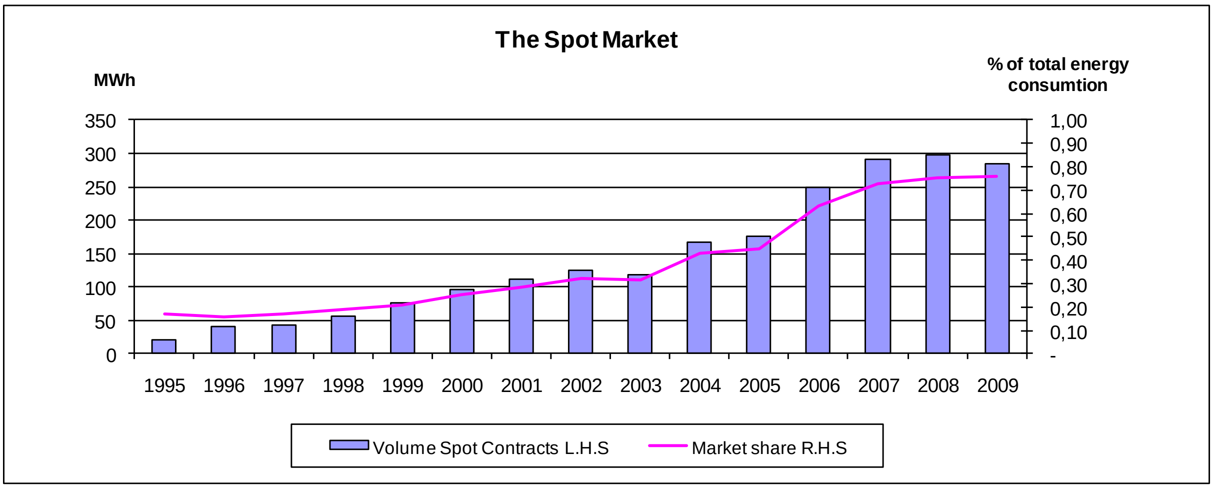
2.1 The physical market

The “physical market” in Nord Pool consists of Elspot and Elbas and is operated by Nord Pool Spot AS. Elspot is a marketplace where day-ahead electric power contracts are traded for physical delivery for each hour of the following day. Market participants submit their bids for each hour of the following day, and a “system price” for each hour is calculated based on the aggregated demand and supply. The system price is set regardless of any capacity limits (“bottlenecks”) in the grid in and between the countries/market areas. The system price can therefore be defined as the market clearing price when there are no transmission constrains. The price is also used as the reference price for the financial market. If there are bottleneck situations between two countries or market areas (Norway is divided into 5 markets and Denmark into 2), the pricing mechanism in the spot market will adjust the price for the involved areas. Internal bottlenecks within a defined market area are managed directly by the national grid operators.

[7] Source: NORDEL

Graph 2 shows the traded volume for the Nord Pool spot market and its share of total energy consumption. There has been a steady increase in total traded volume from 20 TWh and 17% market share in 1995 when the Nord Pool market opened, to 285 TWh and a market share of 76% in 2009.

Graph 2 Traded volume and market share Spot Market[8]



Due to the non-storability characteristics of electricity, market participants may need to adjust their power balance after the closing of the spot market. For this Elbas is available, here one can trade hour contracts until one hour before delivery.

2.2 The financial market

In the financial market one can buy different power derivatives, giving the market participants the opportunity to hedge risk and secure future prices. The derivatives available are; 1) Base and Peak load futures, 2) Forwards, 3) Option and 4) Contracts for Difference (CfD). The reference price for these contracts is the system price defined in the spot market. Trading time horizon is from a minimum of one day to a maximum of 6 years. There are contracts for daily, weekly, monthly, quarterly and annual periods. There is no physical delivery in the financial market. From 2009 it has been possible to trade Nordic, German, Dutch and British Power

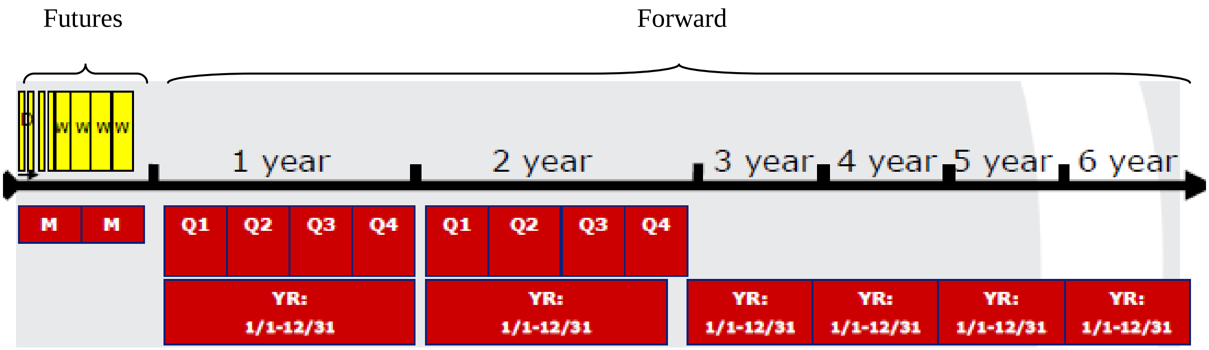
[8] An approximation is used to find the total consumption in the market in the years were new markets participants joined Nord Pool. Norway from 1993, Sweden is included from1996, in 1998 is half of the finish consumption included, and in 1999 half of the Danish, from 2000 the hole marked consumption is included Source: Nord Pool(volume) and NORDEL(consumption))

derivatives on the exchange. Nord Pool Clearing AS is the counterpart in every trade which gives the market participants confidence in the market, increases the liquidity and is a big contributor to the success of the Nord Pool market.

2.2.1 Forwards and Futures

A forward contract and a futures contract are both binding agreements between a buyer and a seller for a fixed amount of power at future time period for an agreed price. The futures contracts at Nord Pool are daily and weekly contracts, whereas forward contracts are traded for monthly, quarterly and yearly time periods, see figure 1. The other difference between these contracts beside the length is how the contracts are settled. For the futures contracts there is a mark-to-market settlement which covers gains or losses from day-to-day changes in the daily closing price of each contract, while forward contracts are settled at the expiration date.

Figure 1 Product structure for forward and futures contracts[9]



2.2.2 Options

An option is a contract between a buyer and a seller that gives the buyer the right but not the obligation, to buy (call option) or to sell (put option) a forward contract on the option's expiration date, at an agreed price. The option can be used as an insurance against high or low prices. The option is a very strong financial instrument in the power market because of the high volatility. Nord Pool lists options for trading for the nearest 2 quarters and 2 years.

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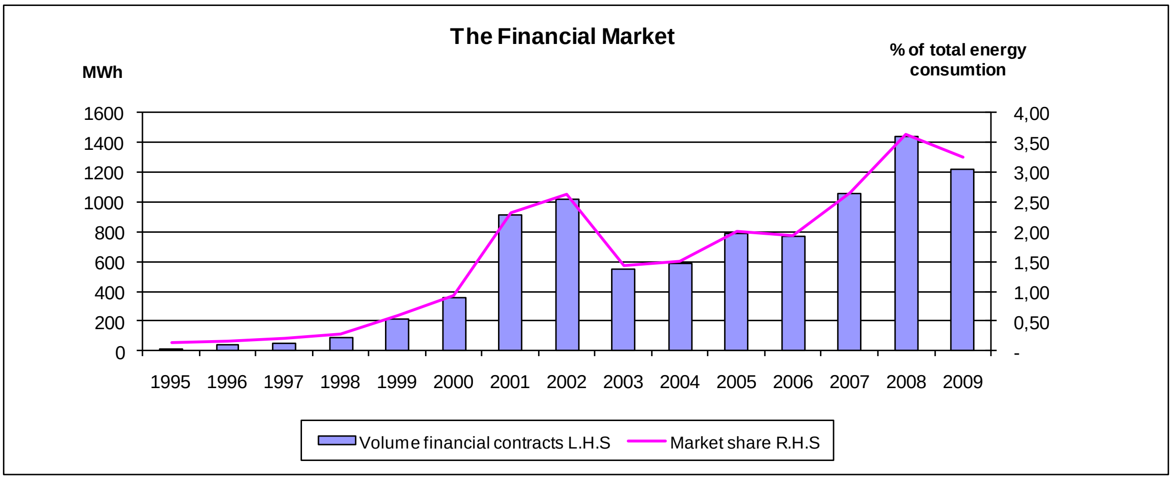
[9] Nord Pool: The financial market, an introduction to Nord pool's financial market and its products.

2.2.3 Contracts for Difference (CfD)

If bottlenecks occur in the grid, the price mechanism will create different prices for the different countries/market areas giving the market participant a certain price risk if they try to hedge just using forward/futures. With the use of CfDs it is possible to hedge away this risk. A CfD is a forward contract with the reference to the different area-prices and the system-price. The price of the contract reflects the market's expected price difference between the two markets, consequently the price difference can be both positive and negative. Nord Pool trades CfD contracts for the nearest 2 months, 3 quarters and 3 years. Kristiansen (2004) concluded in his analysis that CfD traded at Nord Pool on average seems to be overpriced.

The financial market has overall grown rapidly since the turn of the century with a slight decline after the price shock of February 2003, see graph 3. From the time the market was fully operational (included all countries) in 2000 the traded volume have had an annual increase of 14,55%! If one takes a closer look at the market share it reveals a total turnover pr TWh of 325 %. This indicates that by only taking into account the financial market, every TWh of consumption is traded 3,25 times. If we include transactions on the spot market as well, every TWh of consumption is traded 4 times at Nord Pool.

Graph 3 Traded volume and market share financial market[10]



[10] An approximation is used to find the total consumption in the market in the years were new markets participants joined Nord Pool. Norway from 1993, Sweden is included from1996, in 1998 is half of the finish consumption included, and in 1999 half of the Danish, from 2000 the hole marked consumption is included. Source Nord Pool (volume) and NORDEL (consumption)

2.3 The market for carbon emission allowances

Increased carbon emission plays a major role in the ongoing climate change discussions. The Intergovernmental Panel on Climate Change (IPCC) has stated that in order to limit the consequences of climate changes, the increased temperature can not exceed 2 degrees from a pre-industrial level. To reach this goal it is necessary to reduce the carbon emissions by 50-85% compared to the 2000 level. The carbon emission peak needs to be before 2015 for the scenario to strike.[11] The Kyoto protocol[12] is the first step for reaching this goal. It has too low ambitions to reach the IPCC 2 degrees target with its reduction of carbon emission of only 5,2% from 1990 levels for the Annex 1 countries[13] by 2012, but it's a big step in the right direction. The agreement sets the grounds for the emergence of different financial products to meet these new requirements. EU introduced its own emission trading directive in 2005 (ETS) which is the basis for the carbon market. NASDAQ OMX commodities started with sale of European Union Allowances (EUA's) already in February 2005. In June 2007, Nord Pool was the first exchange to offer trading in project-based Certified Emission Reductions (CERs).

2.3.1 European Union Allowances (EUA's)

Each allowance has a "value" corresponding to one tonne of carbon dioxide or carbon equivalent green gases. The price of the allowance defines the cost of emitting the one tonne. When there is a market to trade, an emitter can choose to reduce output of carbon or buy a EUA in the market. Tthe counterpart will reduce their carbon emission by the agreed amount. This gives companies the opportunity to reduce their emissions in the most affordable way, and if the market works it will maximize socioeconomics results when the emission reductions are done by the company that has the possibility to it in a most efficient way. Each company covered by EU's ETS in the member states will receive a certain amount of EUA's for each year. Then it is up to the companies to choose to release the carbon themselves or cut their carbon emission and sell the right to emit to other companies.

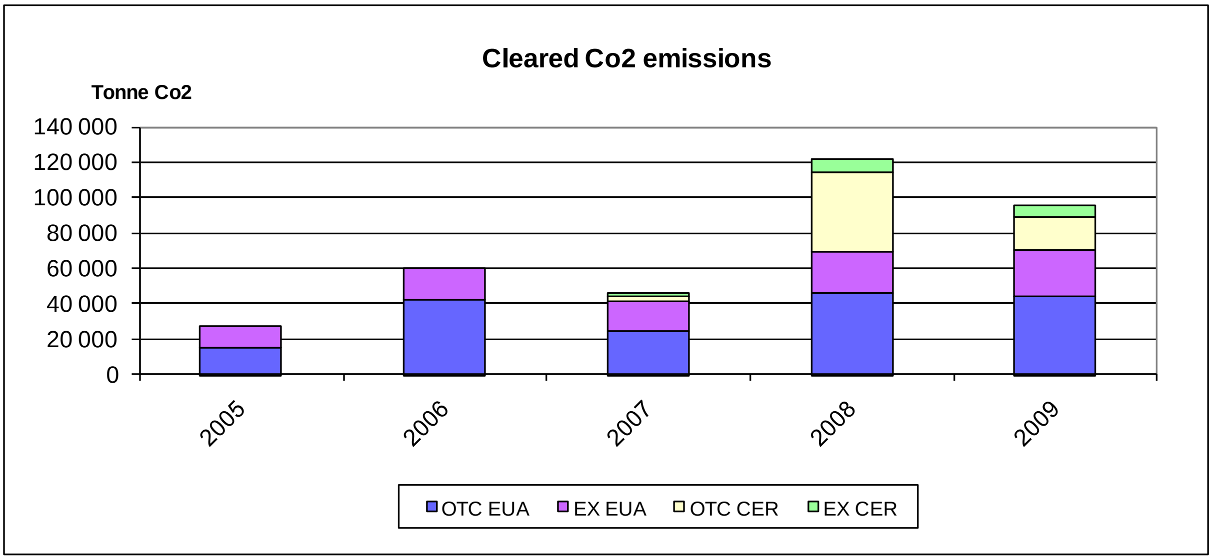
[11] Internet resource nr: 1
[12] Internet resource nr: 2
[13] Annex I countries - industrialized countries and economies in transition 40 countries in total

2.3.2 Certified Emission Reductions (CERs)

A certified emission is a credit obtained by somebody who has achieved a reduction corresponding to one tonne of carbon dioxide or carbon-equivalent greenhouse gas in a developing country. This financial instrument is one of the principles in the Kyoto protocol, where transfer of capital and technology from an industrial country to a developing country is important. For a project to be approved as a CER project it has to be accepted by the UN's Clean Development Mechanism (CDM) executive board, which is a committee that is set to meet the geographical flexibility defined by the Kyoto Protocol[14]. CERs can supplement or replace up to 10% of a company 's EUA requirement.

Graph 4 gives an overview of the development of the carbon emission market at Nord Pool. Traded volume has tripled since it was introduced in 2005, with a peak in 2008. The majority part of the traded volume has been settled at the "over the counter" (OTC) market. The Exchange market has also increased over the period but not substantial compared to the OTC.

Graph 4 Tonne of Co2 emission cleared through Nord Pool[15]



[14] Internet resource nr: 3
[15] Data source Nord Pool FTP server

3. Data

The analysis is based on historical spot and forward prices covering contracts with delivery from 1996 to 2009, i.e. a period of 14 years[16]. All data are obtained from Nord Pool's FTP server. The spot prices (system prices) are from the day-ahead market, and contain hourly prices for each year.

To obtain the weekly prices firstly a daily arithmetic average for hourly prices creates the daily price, which in turn is averaged over a full week to obtain the weekly spot price. The futures price data contain the closing prices for each day of trading, for all contracts.[17] However, in the analysis is only the closing price on the last day of trading in each week used. In order to consolidate the data and make them comparable the forward price for the last day of the week is compared to the average spot price in the same week. See. Botterud et al. (2009) and Gjolberg and Johnsen (2001)

All prices are presented in NOK. The Norwegian bank mid-day exchange rate is the used rate to convert the time series after 2005 to NOK as the Nord Pool Exchange changed the base currency from NOK to EUR in 2005.

On 26 July 2009 there was an oversupply of electricity for some hours during the night. This implies that there was too much electricity generated compared to demand. The system price was therefore set to 0 by Nord Pool[18] but 0,01 NOK is used in the model to make it work. Nord Pool has introduced negative prices from October 2009 in their system to cope with situations like this one.[19]

The reservoir and inflow data (1996-2009) are collected from Nord Pool's FTP server which in turn obtained it from NVE (Norges Vassdrags- og Energidirektorat).While the consumption data are collected from ENTSOE (European network of transmission system operators of electricity)

[16] For the overview picture for spot price in section 1 include data thou trading day 30 April 2010.
[17] The 6 week contract traded at the 29 aug 2003 and 05.sept.2003 (also 5 weeks) is missing in the data sett due to the restructuring of the forward market at this time. The forward price for one month ahead is used for these 3 data points
[18] Internet resource nr: 4
[19] Internet resource nr: 5

The data set is divided into 3 sub periods

Table 2 Overview of analysis period and sub periods

Full sample	01.01.1996-30.12.2009	
1 Sub period	05.01.1996-30.09.2000	Start up face. Nord Pool is still increasing member countries. East Denmark was included 1 October
2 Sub period	01.10.2000-28.01.2005	Mid face. All Nordic countries are members
3 Sub period	01.02.2005-30.12.2009	After introduction of EU ETS. EUA's started to trade 01.02.2005

The first period is defined to be 01.01.1996-30.09.2000 (East Denmark joined in 01.10.00). At this point in time the market was still in the developing stage, and the learning prospects were assumed to be high. It took some time to attain liquidity in the market which could have influenced the price development. The market was still under expansion, i.e. new member countries joined the market during the whole period. There have been some expansion after this period but this is of less importance due to the size of the additional market.

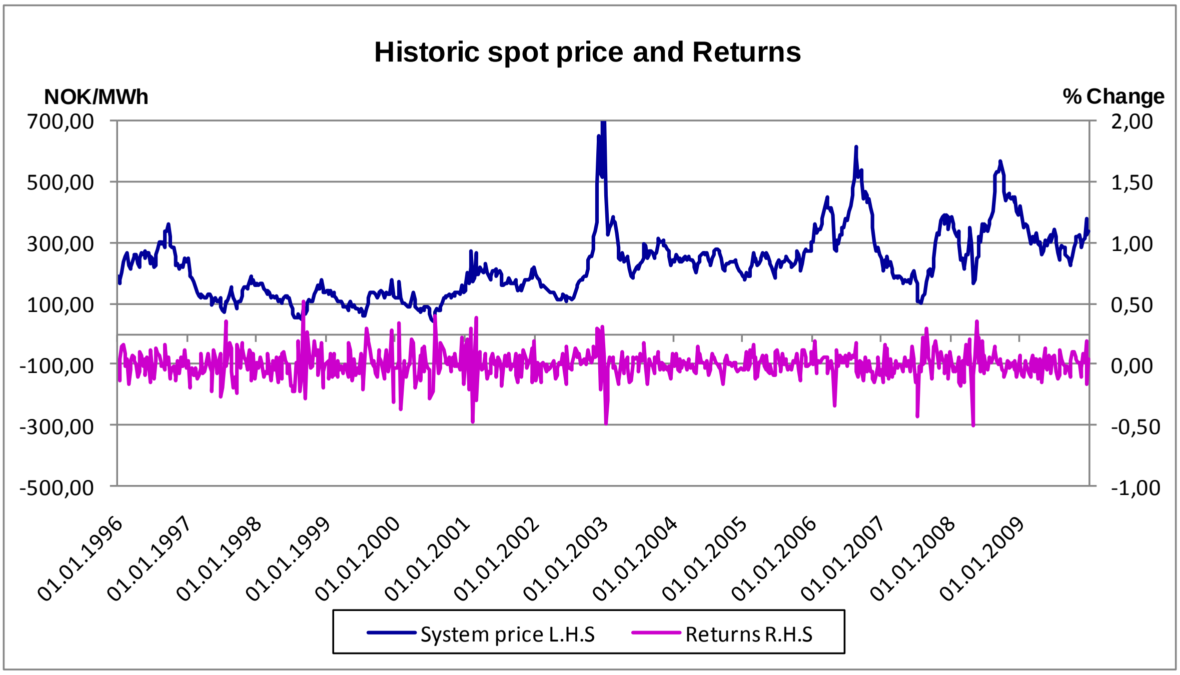
In the mid period (01.10.2000-31.01.2005) all the Nordic countries are members of the exchange. The participants have obtained some experience, so one can assume that there is some increased efficiency in the market.

EU's ETS emission scheme was introduced in 2005 and this changed the cost structure of production (reviewed in section 4.2.4). The base currency also changed from NOK to Euro. By visual inspection of the price history, it seems like it has been a change in the price development from the beginning of this time period. The third period therefore starts at the time ETS started trading 01.02.2005 to the end of the sample period in 31.12.2009

3.1 A quick glance of the spot price at Nord Pool

Graph 5 presents the historical development of the spot prices at Nord Pool. An all time high was observed in the last few weeks of 2002 and the first week of 2003. The price peak was due to a particular cold period that resulted in extreme demand. Another price peak occurred in August 2006 caused by a very dry year which influenced production. October 2008 experienced the third highest price due to the oil price peak. These examples are only some of the factors that have influenced the high prices but exemplifies that there are several variables influencing the electricity prices. The graph also provides an overview of how the price has changed from one week to another.

Graph 5 spot price evolution and log changes



As an introduction to chapter 4, a simple descriptive statistic for the spot price is presented in table 3.

Table 3 Descriptive statistics spot price (weekly data)

	Full sample	1 Sub period	2 sub period	3 sub period
Number of obs	731,00	248,00	226,00	257,00
Mean	226,24	144,75	223,63	307,16
Max	751,72	358,83	751,72	613,37
Min	39,08	39,08	89,46	101,80
Annualized std	109,30	66,54	107,62	98,73

One can see that the average price is quite different for the different periods and it is increasing over time. A simple t-test for differences in the means[20] reveals that there are significant differences between the means in the different sub periods.

It is obvious that also the dispersion of the prices has changed between the different sub periods. The spread between minimum and maximum values are 319,75, 662,26 and 511,57 respectively. Standard derivations are discussed in section 5.4

[20] With t values of 9,5 and 8,8

4. Price determination in the electricity sector

Energy commodity prices are characterized by idiosyncrasies not encountered in financial markets or in any other commodities. This can be explained by many aspects that are unique to the energy market, both in the way the prices are set and specific input parameters that influence the prices. This will be discussed closer in the chapters below.

4.1 Non-storability: balance in supply and demand

Electricity can not be stored in large quantities, and therefore has to be consumed more or less at the same time it is produced. This convergence of supply and demand results in an elimination of arbitrage opportunities over time. Lucia and Schwartz (2001) states that "the non-storability of electricity makes electricity delivered at different times and on different dates to be perceived by users as distinct commodities". The non-storability aspect gives the electricity prices unique characteristics that do not seem to be found in other commodities, for instance price spikes (Weron et al. 2003). The non-storability aspect is also likely to affect the derivative prices significantly since it influences the shape and behavior of the forward curve (Lucia and Schwartz (2001)).

4.2 Price formation

In classic economic theory the price in a market is found by the intersection between the aggregated demand and the aggregated supply curves (i.e. the market cross). This is the way the system price is found at Nord Pool, see chapter 2.1. The non-storability element in the electricity market results in some special properties in the shape of the demand and supply curves, which give the price formation in electricity markets some uniqueness that can not be found in other financial markets or commodities.

4.2.1 Demand Curve

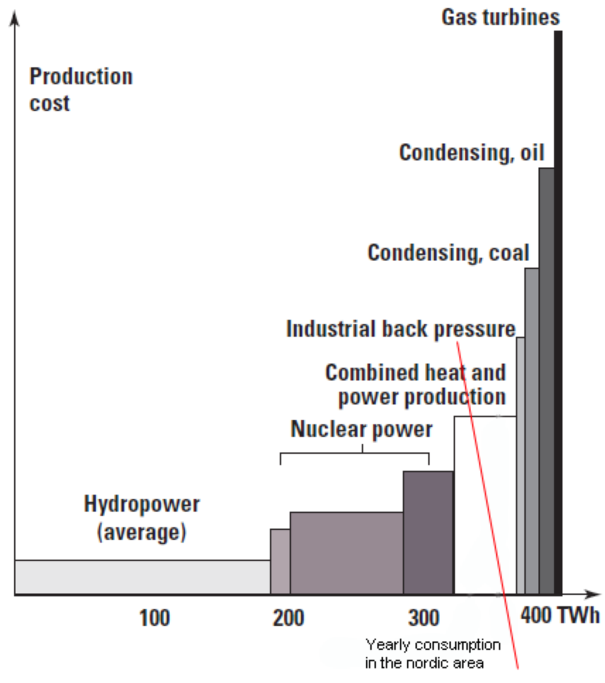
A demand curve shows the hypothetical demand of a product that is desired at different price levels. The demand curve in electricity is typically price-inelastic and can be represented by an almost vertical curve (Fiorenzani (2006)). However, it can exhibit seasonal variations, see chapter 5.2

4.2.2 Supply curve

A supply curve shows the hypothetical supply of a product that would be available at different price levels. In a liberalized electrical market, the marginal cost of production is a good estimate for the supply curve. Within electricity, the curve is called the merit order curve.

Fiorenzani (2006) defines the merit order curve as a map of the ability of the production system to offer different quantities of electricity at different prices at a given time. The merit order is also a way of ranking the available sources of generation in order of their cost of production. Very efficient, but not extremely flexible plants contribute to the left bottom side of the curve, while less efficient and/or very flexible generation plants act in the upper right. The curve will always be upward sloping, but it's shape will depend on the inner physical characteristics of the production system. Figure 2 shows the short run merit order in the Nord Pool market in 1999[21].

Figure 2 Merit order diagram for the Nord Pool market, with standard consumption scenario



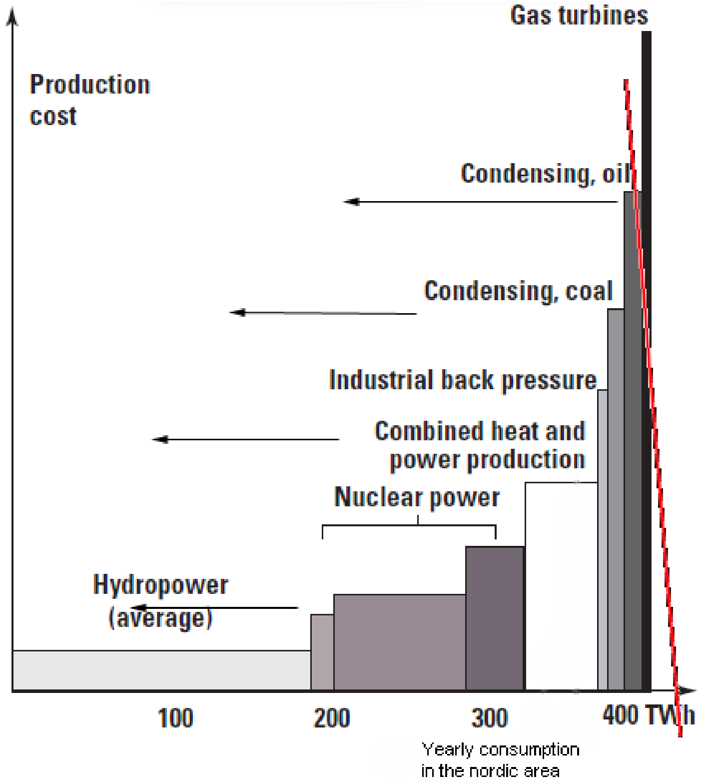
In order to make the curve smoother, variations within each production group could also be scaled. However, the merit curve is only used as a visual presentation in this paper, and smoothness/precision is therefore not that important.

[21] Source: Carlsson (1999)

4.2.3 Consequences of special events

If demand approaches maximum available capacity, the demand curve will exhibit a shift to the right and give significantly higher prices in the short run. A small change in demand at this level can therefore give significantly price spikes. The Nordic market that is so heavily reliant on hydro power can also give significant price spikes. If for instance there has been a dry year, less hydropower is available which will shift the supply curve to the left and result in the same effects. A specific merit curve is only valid in the short run. In the long run new generation capacity will change the sizes of the bulks and subsequent the supply curve.

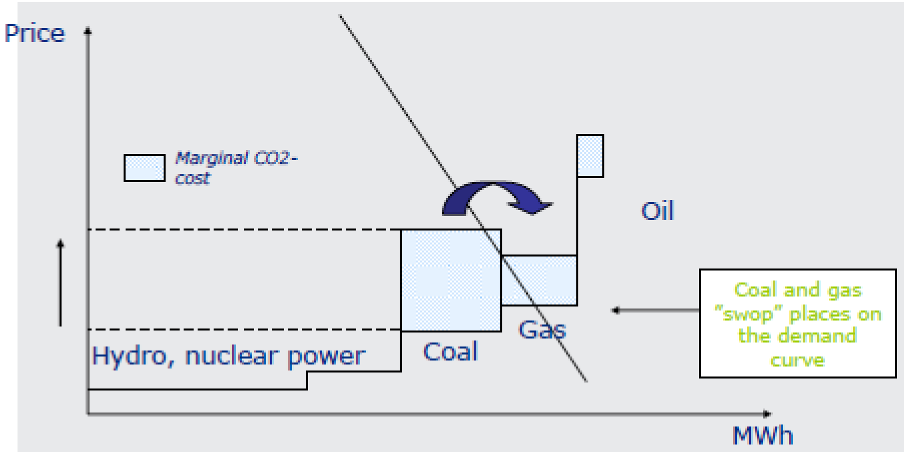
Figure 3 Merit order diagram for the Nord Pool market, special events scenario



4.2.4 Consequences of emission quotas on the merit order

The introduction of EU ETS has changed the prices of electricity. More environmental and efficient production systems are rewarded and production systems that have a high CO2 emission have increased their marginal cost. This has resulted in a swap between gas and coal in the merit order, see figure 4. If the market works as intended it will contribute to the development of technology and increase the competiveness of renewable energy.

Figure 4 Merit order after introduction of emission quotas[22]



4.3 Hydro power dominance

The Nordic power market is dominated by hydropower. In Norway almost 99% of generation is from hydropower and in the whole Nordic regions hydropower generation accounts for 57% of total production[23]. This reliance on hydropower gives the Nordic power market special features that are particular for this market. The non-storability feature mention in the previous chapter is not that strong in the Nordic region. This is because hydropower producers can store the water in reservoirs, which gives the producers some degree of flexibility and opportunity to shift production to periods with higher prices. Note that this movement trough time is not possible for the consumers, giving the market an asymmetry where the producers have market power. Gjolberg and Johnsen (2001) investigate this aspect and found that there are some discrepancies in price formation that may indicate market power that is brought into play. A further discussion of the storability in hydropower is given in chapter 6.2.1

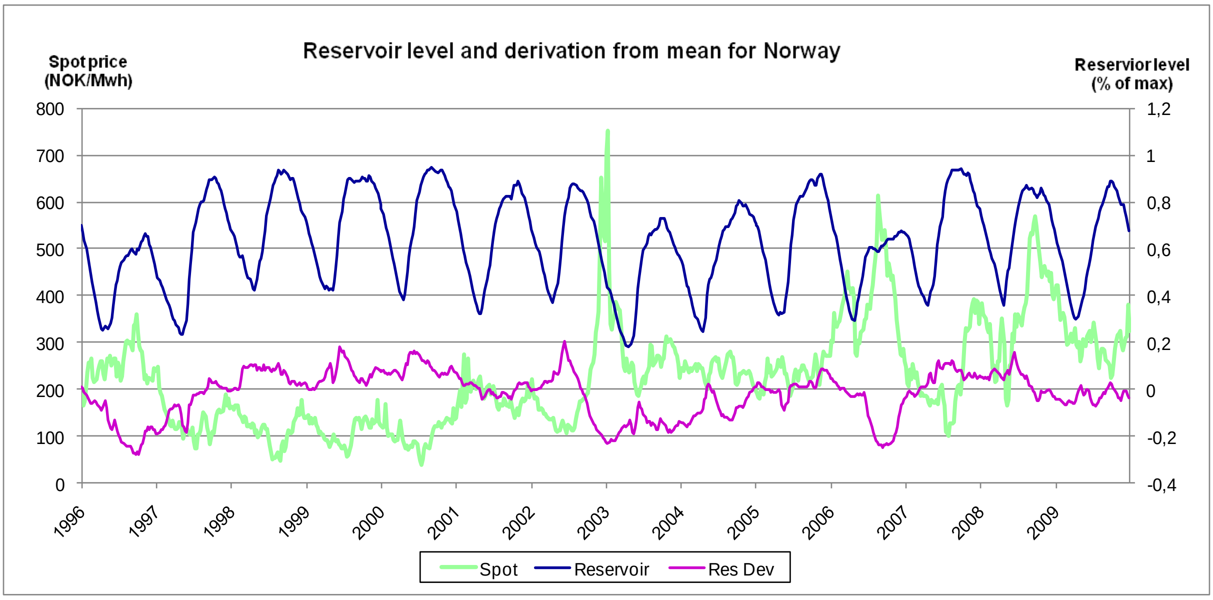
4.3.1 Hydrological resource influence on prices.

Since the majority of electricity production in the Nordic region is generated from hydropower, the prices of electricity are highly dependent on the state of the hydrological resources. Of hydrological resources that have an influence on the electricity prices one can mention inflow, reservoir level and snow pack (Botterud et al.(2009)).

[22] Nord Pool: Building a secure market, NTNU 28.10.2008, Peder Soderlund
[23] Nordel 2008

The relationship between hydro conditions and the spot price has been analyzed by many. Botterud et al. (2009) (analysis period 1996-2006) finds that the reservoir level has a clear impact on prices. Graph 5 updates their approach. This shows that there is a clear relationship between the derivation from median reservoir levels and spot prices. This is especially visible at the major price increase of winter 2002/2003, in 1996/1997 and in the summer of 2006.

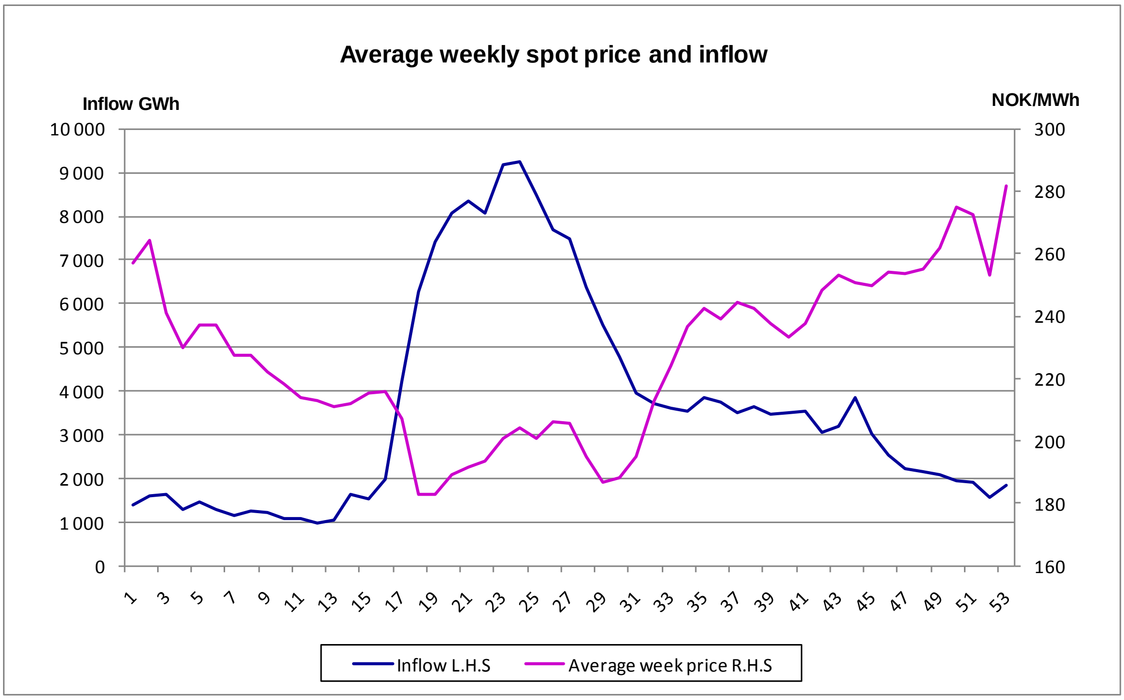
Graph 6 Average weekly spot prices, percentage reservoir level at end of week for Norway and derivation from median reservoir level (1996-2009) for Norway.



The second part of the period (after 2003) has a substantial higher part of reservoir level that is below the median. The periods are of equal size, share of observations that are higher than the median is for the first period 62% and the second 38% (own calculations). Botterud et al. (2009) believes that this can contribute to explain the observed increase in prices in the last period.

Another hydrological variable that is widely accepted as a price determination variable is inflow. Fleten and Lemming (2003) states that there are high levels of inflow in spring and summertime when snow in the mountain melts. Due to capacity constraints, these plants must produce at high levels during the summertime in order to avoid costly spill resulting from overflow in the reservoirs. This naturally creates a downward pressure on prices, which is exacerbated by a low demand caused by high summer temperatures. A comparison of the average spot price and the average inflow from 1996-2009 is presented in graph 7. The graph shows a clear tendency for this inverted relationship between the average spot price and inflow.

Graph 7 Average weekly spot price and average inflow 1996-2009



5. Empirical properties of electricity prices

The idiosyncrasies found in electricity prices compared to other commodities results in some empirical properties that can be identified and categorized using simple empirical techniques. In this section a further look at mean reversion properties, regular patterns, spike statistics, data clustering and volatility is presented.

5.1 Mean-reversion

In general terms, mean-reversion is a tendency for the price to pool back towards the normal level (i.e. mean). A price increase is followed by a price decrease. Electricity prices are in general regarded to be mean-reverting ex. Lucia and Schwartz (2001), Lund and Ollmar (2003) and Escribano et al. (2002). Escribano et al. (2002) state that the block structure of the supply side discussed in chapter 4.2.2 gives a natural mean reversion of the energy prices. They also state that the prices are mean-reverting because of the price determining variables are mean reverting (ex. the cyclical nature of the weather). Lund and Ollmar (2003) find that in cases were there are unusual load conditions there are a fast mean reversion. Over longer periods the electricity prices shows a slow reverting process due to the timeliness of the hydrological balance.

5.2 Regular patterns

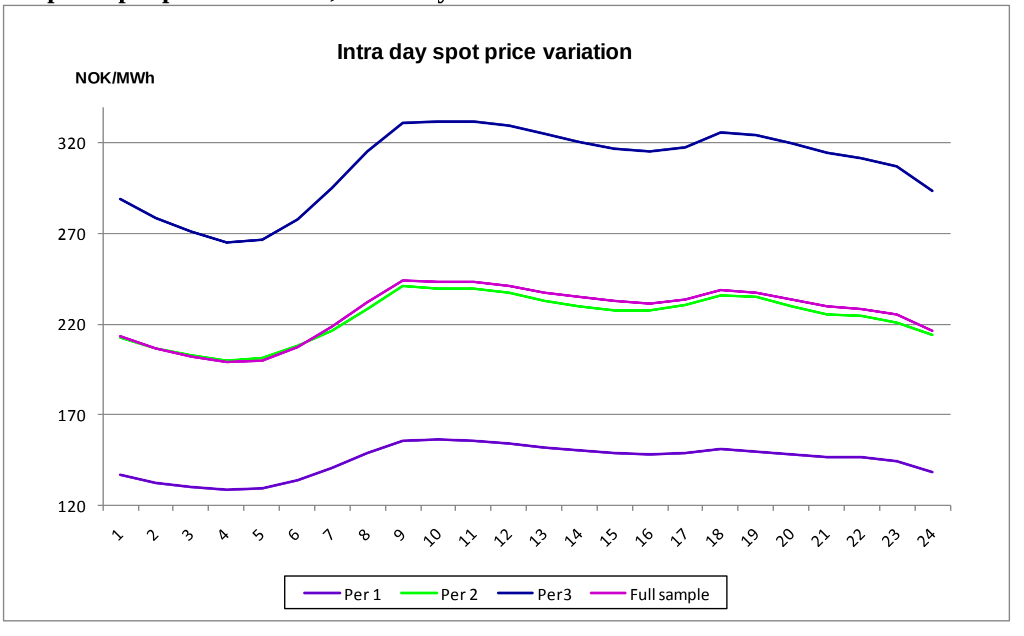
Systematic patterns in the spot prices at the Nord Pool market have been investigated and identified by many, for example Lucia and Schwartz (2001), which identify patterns within a day, week and yearly through inspection of graphs and investigations of autocorrelations. Another example is Erzgraber et al. (2008) which investigate long-run correlations through the measure of the Hurst exponent and MF-DFA[24] analysis. They found clear systematic patterns within the day and week. They could however not find a clear pattern within the year. To illustrate this each pattern is evaluated below.

24 Multifractal detrended fluctuation analysis

5.2.1 Intra-day pattern

Demand for electricity varies greatly within the day and influences the price level. An inspection of graph 8 reveals a pattern that is clearly related to business activity: low prices during the night, increased prices during business hours followed by a price decrease after regular hours. There is also a small peak around the time when people get home. All sub periods had the same pattern but as previously mention there is a clear difference in the price level between the periods[25].

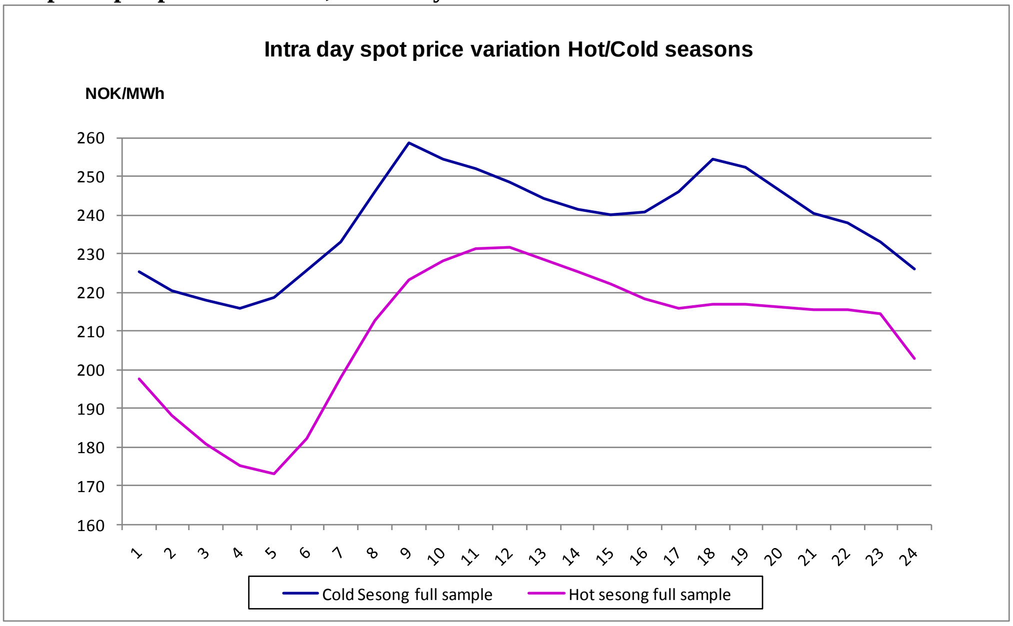
Graph 8 Spot price variation, intra-day



In graph 9, the period has been divided into cold and hot season[26] and one can see that both seasons have similar pattern throughout the day with exception of the peak after business hours. This is obviously caused by the lack of necessity to heat up the homes during the hot period.

25 Period 1 has exactly the same shape but due to the scaling of the graph this is not that obvious
26 This fact was previously detected by Johnsen et al. (1999). A cold season is defined here as any period running from October through April, and a warm season from May through September

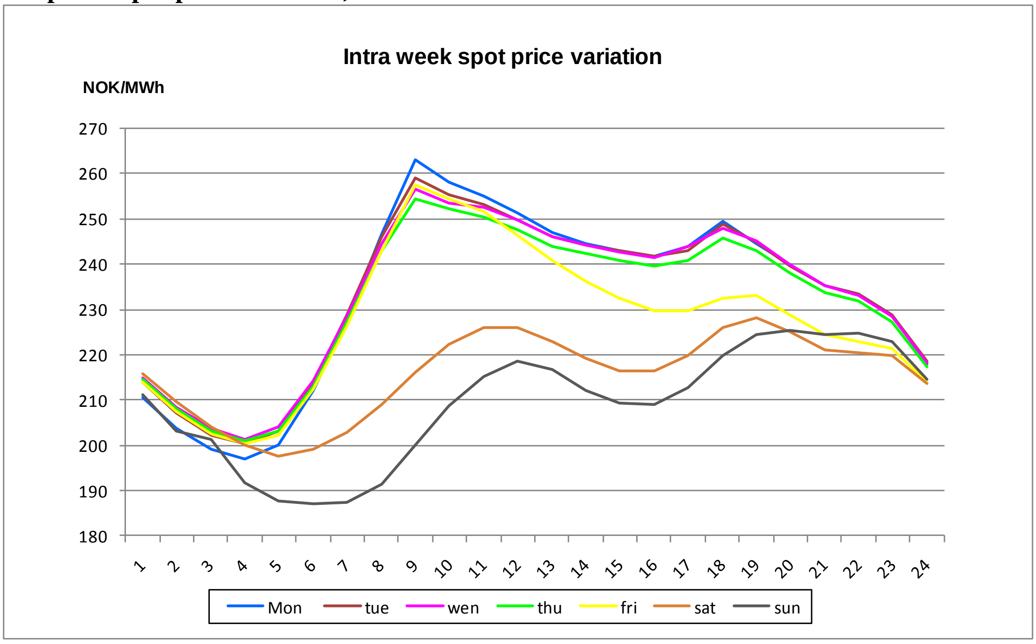
Graph 9 spot price variation, intra-day cold and hot seasons



5.2.2 Intra-week patterns

Graph 10 shows that within the week there is also some predictability in the time series. Monday through Friday the prices are somewhat the same, with exception of Friday after 12:00. Weekends exhibits lower prices than workdays.

Graph 10 Spot price variation, intra-week

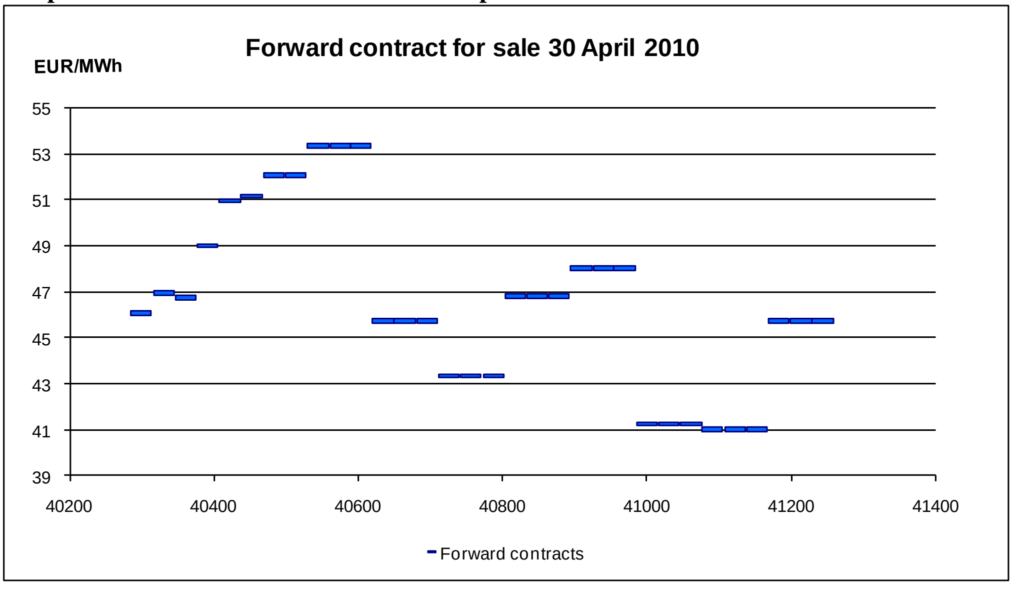


5.2.3 Yearly patterns/seasonality

Many articles ex. Johnsen (2001) and Lucia and Schwartz (2001) argue that the Nord Pool area is seasonal by structural nature. Electric heating and shorter period of daylight during the winter combined with colder temperatures and lower inflow result in clear seasonal patterns. However, this clear, yearly seasonality of the power price seems to be less distinct in the recent years, as pointed out by Botterud et al. (2009). They state that the recent increase in prices may be partly due to a moderate increase in the demand combined with little new capacity. This may have caused a positive shift to a higher level in the merit order curve (figure 3) which in turn results in a higher share of the generation capacity to come from production plants that are not influenced by clear, seasonal price determining variables (inflow, temperatures, and reservoir level etc.). Another element that can explain this aspect is the increased share of financial speculators in the market and the fact that Nord Pool now is more closely connected to continental Europe, which is not that influenced by the seasonal price determining variables due to their different production mix[27].

Since the clear seasonal pattern is not that obvious anymore, it is interesting to see whether the forward contracts yet to be delivered exhibit any seasonality. Graph 11 provides an overview of the monthly and quarterly contracts that are up for sale on 30 April 2010. One can se that there is some seasonality included in the forward price, e.g. the prices increase until late February 2011, thereafter it is a substantial decrease towards the summer before they increase again towards winter 2012

Graph 11 Forward contracts for sale 30 April 2010



[27] Internet resource nr: 6

5.3 Spikes and data clustering

As mention in chapter 4.2.3, the electricity prices often exhibits price spikes. Kaminski (2005) states that positive spikes happen when key generation assets suffer an outage or when there are unusual load conditions, i.e. demand reaches the limit of available capacity. When the relevant production asset is fixed or demand recedes, the price will return to a more typical level. Negative spikes occur when operating cost or constraints limit the ability of generators at or near the margin to limit production during brief periods of reduced demand.

Lucia and Schwartz (2001) use kurtosis to show that electricity prices exhibit extreme prices. They found a kurtosis coefficient of 3,5 in their analysis, which means that extremely low and high prices have a higher probability of occurrence than that dictated by normal distribution with the same variance[28]. They also identified a positive skewness coefficient of 0,75, indicating that it is a larger probability for high extreme values (1993-1996). An update of the kurtosis and skewness are presented in table 4, showing that the kurtosis and skewness have increased since Lucia and Schwartz analysis. The second period is very out of sync with the rest of the sample with a kurtosis coefficient of 14,2 and a skewness of 2,5993. This is highly influenced by the price spike in the winter of 2002/2003.

Table 4 Overview of the spot price kurtosis and skewness

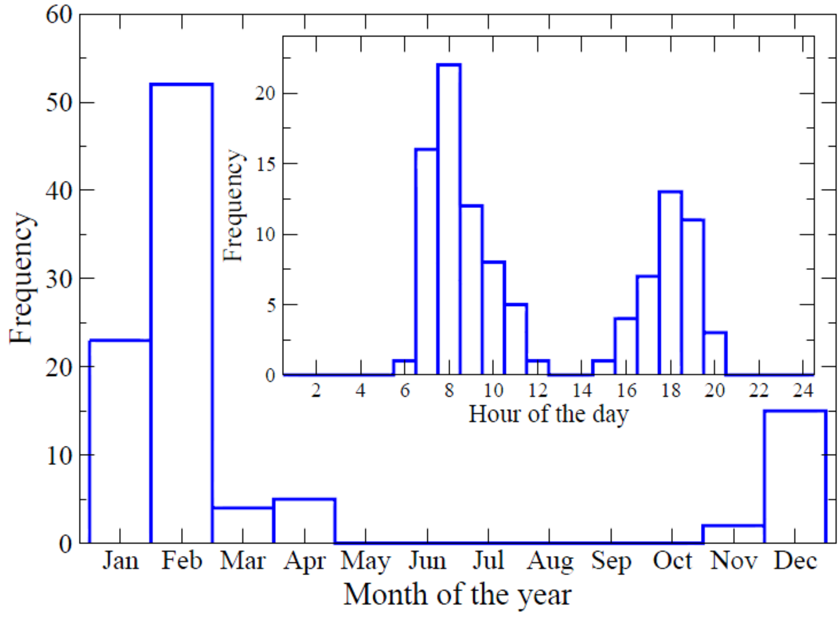
	Full sample	1 period	2 period	3 Period
Kurtosis	4,695	4,0235	14,204	3,1086
Skewness	1,037	1,0235	2,5993	0,5721

If one looks at the third period it has been a considerable change, the prices in this period is almost normal distributed. This may seem strange when one looks at the time series for this period. It is much more volatile than previous sub periods, but increased volatility is taken into account through the standard derivation, what appears to be spikes are covered through the increased volatility.

Perello et al. (2006) investigate the appearance of data clustering, at Nord Pool they found that the dramatic price variations take place during periods of high consumption. There is therefore a presence of seasonality in spike statistics, see figure 5. However, this does not mean that the spike events follow a deterministic rule.

[28] If the kurtosis is 3 it is normal distributed

Figure 5 Frequency distributions of the 100 largest hourly return events *vs.* month of year and hour of the day (inset). (1993-2005)[29]



5.4 Volatility

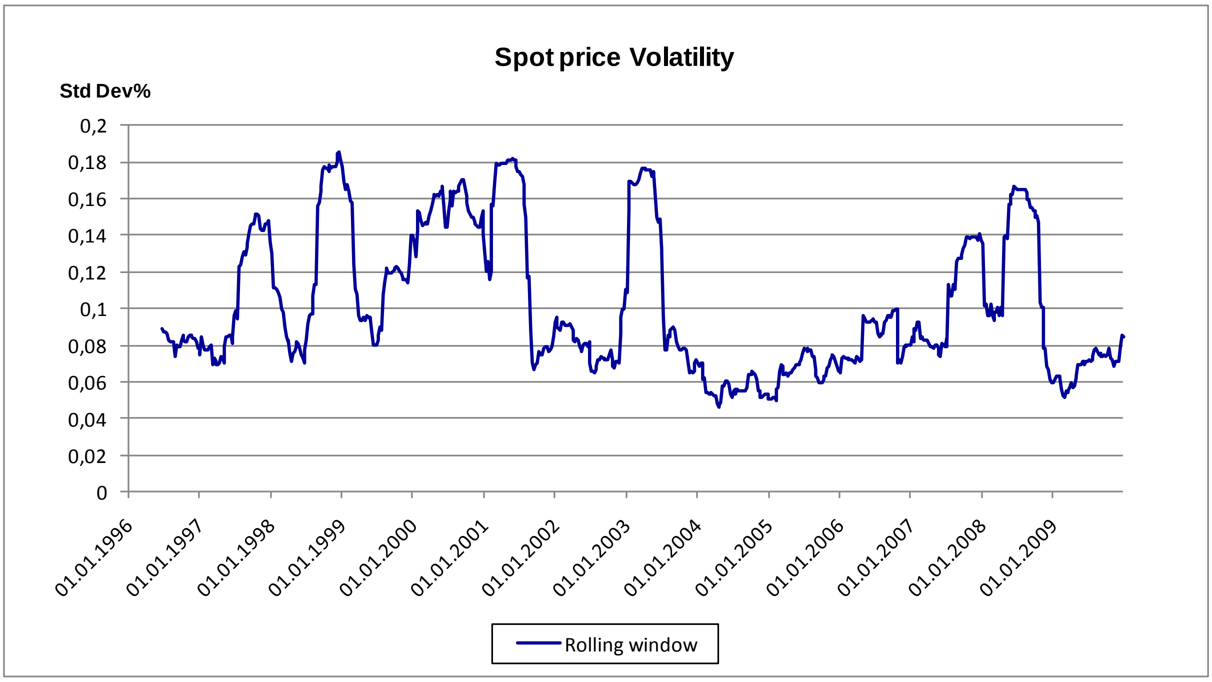
Volatility is price dependent as fluctuations in demand move different power generating assets into the market. Higher levels of demand bring assets on the upper, steeper portion of the supply curve into production. Small changes in demand at this level will result in high price variations, (Kaminski 2005).

Electricity prices are highly volatile, measured by standard volatility measures like standard deviations. Lucia and Schwartz (2001) find an annualized standard derivation of 189% based on daily observations. An update for the full period (1996-2009) gives the same result. Differences between the periods are minor[30].This variance is under the assumption that the volatility is constant over time. Graph 5 in chapter 3.1 reveals that this is not the case. Volatility tends to be time varying and shows volatility clustering. If a time series has constant volatility it is homoscedastic. When volatility changes over time it is called heteroscedastic. Electricity prices are therefore heteroscedastic. There is a seasonal pattern in the volatility clustering which gives the volatility some predictability, with typical low and high volatility periods during the summer and winter seasons, respectively (Perello 2006)

[29] Source: Perello et al. (2006)
[30] Annualized standard deviation sub period 1= 194,86 period 2=180,35 and period 3=195,80).

Graph 12 presents the evolution of the volatility in the market, given a rolling window of 26 weeks.

Graph 12 Spot price volatility, rolling window 26 weeks.



This illustrates both the time varying volatility and the volatility clusters. However, it is worth mentioning that this estimation procedure involves elements of ghost features, which means that major changes in estimated volatility could occur merely because of influential observations leaving and entering the sample[31].

One can see that although a much higher standard derivation was reported for the last period, the rolling window estimate shows a different picture. The reason for this phenomenon is that in spite of the higher price volatility in the later period, the weekly returns are more stable. This is also visible in graph 4 in the previous chapter. Indicating that prices are relatively more stable, but the increased price spikes drive the price volatility up.

All of these commodity specific characteristics are contributors to explain how spot prices in the electricity market are set. The following chapter presents how the forward prices are determined in a market and how forward and spot prices historically has interacted at Nord Pool.

[31] Source lecture notes: NHH FIE435APPLIED FINANCE Professor Richard D. F. Harris

6. Forward price formation

A forward contract is a binding contract that calls for delivery of a commodity at a specified delivery or maturity date, for an agreed-upon price (futures price), to be paid at contract maturity[32]. A forward contract at Nord Pool calls for delivery of 1 MWh.

The different theories of how forward prices are found in a market are presented in this chapter, starting with a general approach before commodity distinctive variations are reviewed. The chapter ends with a quick glance at the forward prices at Nord pool and the historic relationship between spot and forward prices.

6.1 Financial Spot-future price relationship

In financial markets, the spot-forward relationship is defined as;

$F_{t,T} = s_0(1 + r_f)^{T-t} - PV(DIV)$ (Discrete time) or $F_{t,T} = s_0 e^{(r_f - \delta)^{T-t}}$ (continuous time),

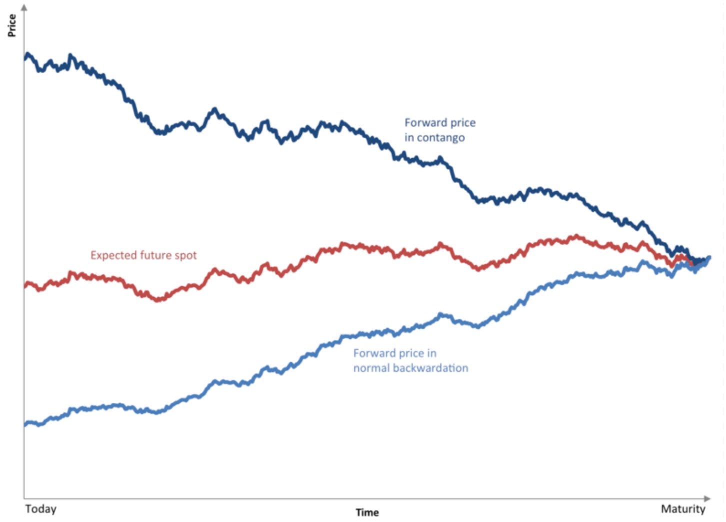
where:

- $F_{t,T}$ is the futures price observed at time t for a contract with maturity at time T,
- s_o is the spot price
- r_f is the risk free rate
- DIV/δ is dividend (discrete and continuous).

The difference between the forward and spot price reflects the cost and benefits of delaying payment and receipt of the asset. The one that holds the asset has to be compensated for risk free interest forgone by not placing the value of the asset in the bank, while the forward contract holder needs to be compensated for dividend (δ) forgone by not holding the asset. The relationship is often called cost of carry. If the investors are rational and there are no market limitations, the assumption of no-arbitrage opportunities will converge spot and future prices at delivery date, see figure 6

[32] Bodie et al.2008

Figure 6 spot and future convergence at delivery



If the forward price is higher than the spot price at time t, the market is said to be in contango while the opposite scenario is called backwardation.

If the asset in question is a commodity, the relationship is a bit more complex and is the topic in chapter 6.2.

6.2 Commodity Spot-future price relationship

The relationship between spot and futures is different for commodities than for a strict financial asset. There are two main theories that investigate this relationship; the theory of storage and the risk premium theory (Botterud et al. (2009)).

6.2.1 Theory of storage

Seasonality in supply or demand may require storage of a commodity. A supplier has the choice between selling today for price S_0 or store the asset for future sale. The latter will only happen if the present value of selling at time T (including storage cost) is at least as great as the value of selling today:

$$F_{t,T} \geq S_t e^{(r_f + W)(T-t)},$$

Where, W is the future value of all storage cost (rent of storage space, insurance, waste etc.)

The holders of the asset have a benefit of owning the physical commodity, expressed as convenience yield (CY). CY reflects the market participants' expectations (or fear) related to the availability of the commodity during the contract period. The total spot-future commodity relationship is therefore;

$$F_{t,T} = S_t e^{(r_f + W - CY)(T-t)}$$

When inventory is low, the CY can be higher than the sum of capital and storage cost. This will result in a negative spread between future and spot prices (called "the basis"), and the market is said to be in backwardation.

Electricity is, as stated in chapter 4.1, a non-storable commodity. This model is therefore not suitable for most electricity markets. Gjolberg and Johnsen (2001) and Botterud et al. (2009) state that for the Nord Pool market the model is somewhat valid due to the producer's possibility to store water in their reservoirs and the large share of hydro power in this market. There is no direct cost connected to storage of water if there is available capacity in existing reservoir. If the reservoir is approaching maximum capacity, the producer can risk an economic loss due to potential spillage of additional water flowing out off the reservoir.

6.2.3 Risk premium theory

The risk premium theory explains the price of a futures contract in terms of the expected future spot prices $E_t(S_{t+T})$, and a risk premium.

$$F_{t,T} = E_t(S_{t+T})e^{(r_{f,t} - i_t)} = E_t(S_{t+T})e^{-p_t},$$

where

- i_t is the commodity's risk appropriate discount rate,
- $r_{f,t}$ is the risk-free rate.

According to the theory, the future price and spot price will only be equal when the risk premium is zero. The presence of a risk premium can be explained in two ways.

The first alternative is with a systematic risk approach similar to the CAPM[33]. If the commodity has more systematic risk than other assets in the financial "universe" it will have a higher i_t rate of return, resulting in a positive risk premium.

The second alternative is the risk premium explained by specific market conditions, ex. a dominance of risk-averse producers wanting to hedge their production. This could result in excess supply for long term futures contracts resulting in lower future prices than spot prices (a negative risk premium). Botterud et al. (2009) state that in a hydro dominated energy market like Nord pool there is a significant difference in flexibility between supply and demand. Supply can store water while waiting for higher prices in the future. The demand side has, however, low flexibility in adjusting their demand according to the price. It would therefore be sensible for the risk-adverse demand side's participants to lock in as much as possible of expected future demand in the futures market. This contrasting relationship could lead to an excess demand for long futures contracts which would translate into a positive risk premium.

The two theories are not mutually exclusive, but the latter can be used for a non-storable commodity without special considerations, and is therefore used in analysis for many electricity markets.

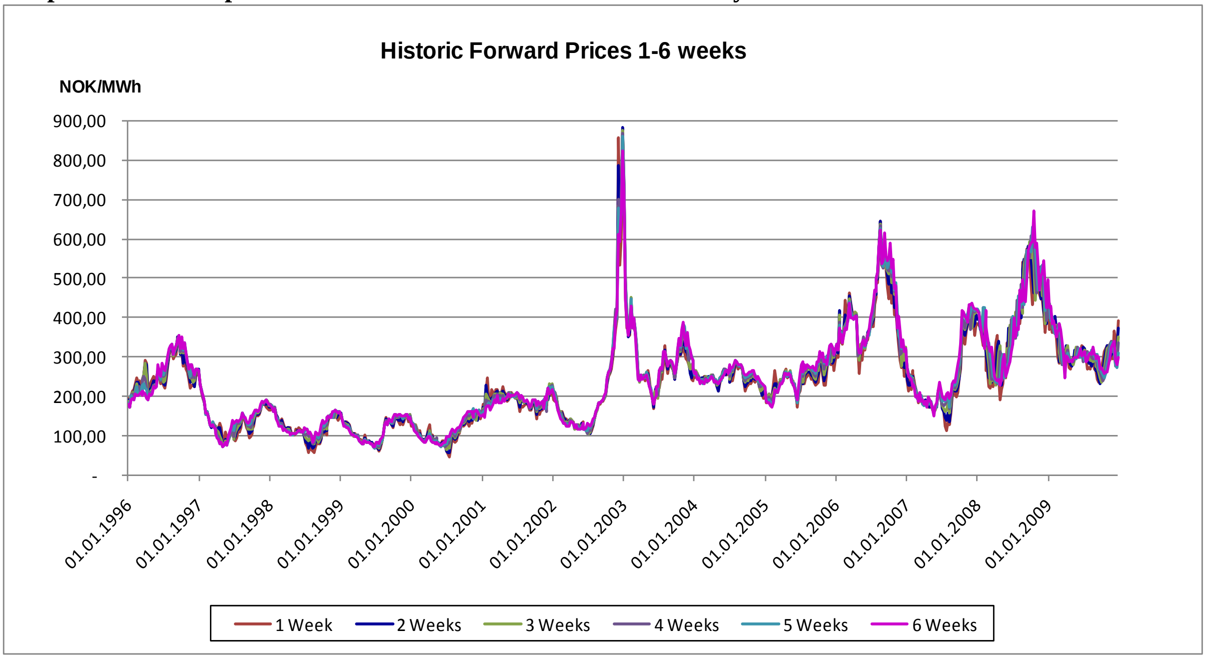
6.3 Forward prices at Nord Pool

Graph 13 provides an overview of the price history for forward contracts with delivery 1-6 weeks into the future. They basically follow the same pattern as spot prices (graph5). This close relationship is also visible in the high correlation coefficient. Between the spot price and any given forward price, the correlation is above 95,7%, and the correlation between any two futures prices is above 96,3%. It is assumed that the forward prices have the same essentials

[33] Capital asset pricing model. For a closer explanation see e.g Copeland and Weston 1988; Financial theory and corperate policy

as the spot prices analyzed in chapter 5 and the specifics of future prices are therefore not analyzed further. A more interesting perspective is how the spot and forward prices have interacted. This is analyzed in the following chapter through measures of basis and forecasting error.

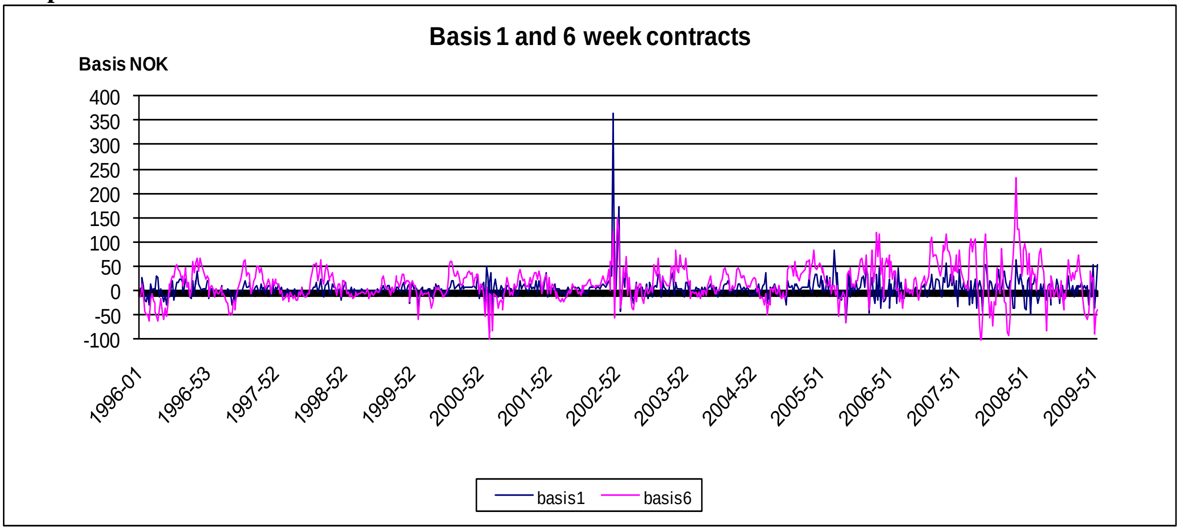
Graph 13 Forward prices for contracts with 1-6 weeks to delivery



6.3.1 A closer look at the basis

The basis is, as previously defined, the difference between futures- and spot prices at the same observation time. Graph 14 provides the basis for 1 and 6 weeks contracts.

Graph 14 Historical basis for 1 and 6 weeks contracts 1996-2009



It can clearly be seen from graph 14 that the basis shifts between being positive and negative. This is caused by seasonality in either the spot prices or risk premiums (Lucia and Torro 2008). The basis is positive in more than 59% of the times for all the contracts, indicating that the market is primarily in contango. This is also visible in the positive mean value reported in table 5.

Table 5 Absolute and relative basis at Nord Pool; 1-6 weekly contract 1996-2009

Full sample		Basis 1	Basis 2	Basis 3	Basis 4	Basis 5	Basis 6
Absolute basis	Mean	3.79	8.27	11.06	12.54	13.70	14.06
	Std.dv	22.21	24.33	27.82	31.68	34.08	35.95
Relative basis	Mean	1.74 %	3.89 %	5.46 %	6.46 %	7.25 %	7.69 %
	Std.dv	8.04 %	10.86 %	14.01 %	16.76 %	18.83 %	20.25 %

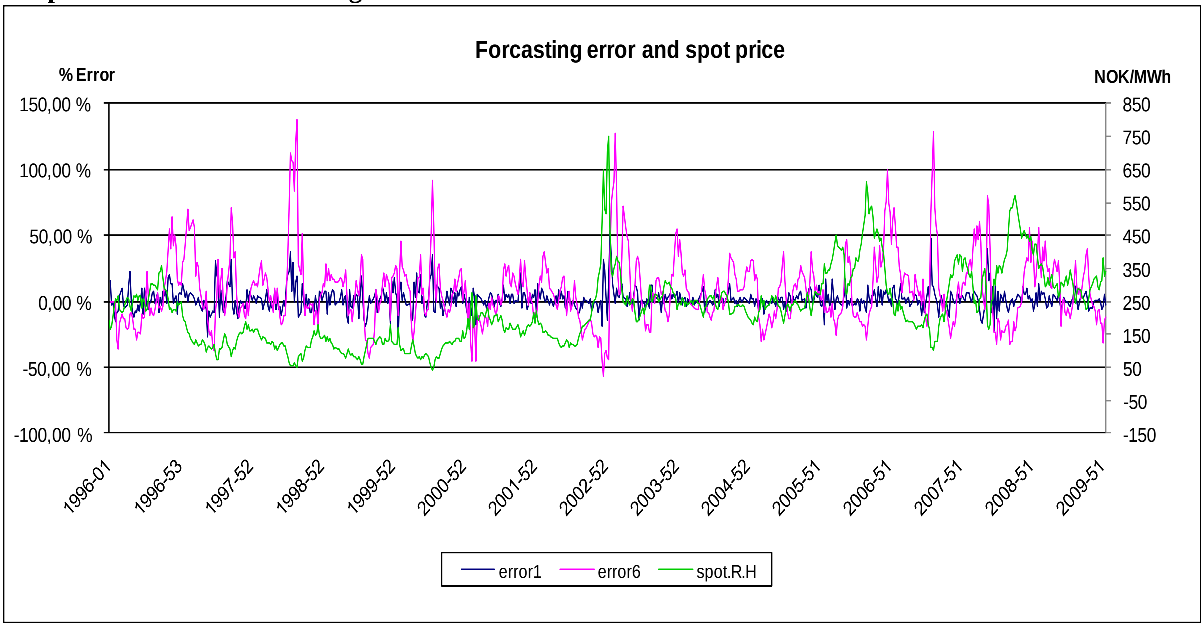
Table 5 reports descriptive statistics for the basis, both in absolute and relative values (were the relative is taken as percentage of current spot). The mean relative basis for one week contracts has been 1,74%. If one annualize this it will give an annual return of 90,5% when holding 1 week contracts through a whole year. This is substantial higher than the average return in the financial market.[34] Gjolberg and Johnsen (2001) state that this is very large compared to what could be expected by market fundamentals and they raises the question if this is caused by market power from the producer side.

6.3.2. Future price forecasting error

In an efficient and unrestrained market it is believed that the forward price is a good estimate for the subsequent spot price[35]. The forecasting error is found by subtracting the spot price for the i'th following week spot from the forward contract with i weeks to delivery ($F_{t,i} - S_{t+i}$). If the mean forecasting error is zero, one could say that forward price is a good estimate for the future spot price. Graph 15 provides an overview of the forecasting error in percentage of the spot prices for the 1 and 6 weeks contracts.

[34] Return on world asset classes 1900-2005 has there been a nominal return of 8,9 % Global investment year book 2005
[35] Disregarding capital cost etc. This simplification does not compromise the results that much since this analysis is only for products with a short term window

Graph 15 Historical forecasting error 1 and 6 week contracts 1996-2009



It is obvious that there is substantial forecasting error both in the 1 week forward prices and in the 6 week forward prices. The error is as expected much larger for the 6 week horizon, ref. section 6.1 where it was argued that the spot and forward price will converge at delivery.

Gjolberg and Johnsen (2001) argue that difference in flexibility between consumers and suppliers will generate an excess of long hedging demand at Nord Pool, with consumers paying a risk premium. They also state that this aspect could generate a “reservoir rent” which is a cost the consumers need to “pay” for storage of water to later periods. The average mean error in table 6 supports this hypothesis.

There have been substantial forecasting errors for all contracts, where the mean values are all positive. All forecasting errors are significantly larger than zero despite wide dispersions in both directions. Looking at the min/max values in table 6 one can see that the futures price has overshoot the spot price with a much higher error than the reverse case.

Table 6 Futures price forecasting error (percent of spot price) 1 to 6 weeks ahead

	Mean	Std.dv	t-Value	Min	Max
error1	1,66 %	8,26 %	5,44**	-27,5 %	54,0 %
error2	4,23 %	15,59 %	7,33**	-36,6 %	115,2 %
error3	6,04 %	19,88 %	8,20**	-38,9 %	158,3 %
error4	7,10 %	22,40 %	8,55**	-43,1 %	165,7 %
error5	8,01 %	24,66 %	8,76**	-50,4 %	146,6 %
error6	8,64 %	26,50 %	8,77**	-56,9 %	138,4 %

t-value: test for H0. Futures price unbiased predictor i.e. mean error=0

In January 2003, the future price did overshoot the spot price by 165,7%. After this shock major errors are found around the times of the obvious spikes in the spot price. It seems like the market is now quicker to incorporate new information in the future price. Nevertheless, the spiky nature of the electricity price results in larger forecasting error because the spot price has in most cases returned to a normal level before the contract is due for delivery. The errors before 2002/2003 have no clear explanation.

7. Efficient market hypothesis

The efficient-market hypothesis (EMH) asserts that financial markets are "information efficient". That is, one can not consistently achieve returns in excess of average economic reasonable returns on a risk-adjusted basis given the information publicly available at the time the investment is made[36]. An efficient market is one where information is rapidly disseminated and reflected in prices. The current price should reflect all relevant and ascertainable information. The EMH is evaluated by the “predictability” of changes in the price.

Fama (1970) distinguishes three categories of market efficiency; weak, semi strong and strong. The week market efficiency assumes that the current prices already reflect all information about historical prices and volumes. It is therefore not possible to predict future prices by analyzing historical prices. The prices follow a true random walk.

A market is semi strong efficient if all public available information regarding the “asset” is reflected in the price. For electricity this can be reservoir levels, inflows, imports etc. Since investors have access to this information from public available sources, one would expect it to be reflected in the prices. Interpretation of the importance/influence of variables may however differ from investor to investor. This could give different results ex post, however ex ante, one can assume that some will have a positive error and others will have a negative error. In information efficient market the expected mean error is therefore zero. As the market matures the participants will close in on a unison assessment of how the variables influence the price, they will still make errors but with a another magnitude.

In a strong efficient market, the price includes all information, including insider-information. This is an extreme example and is not applicable for a real market.

[36] Source: Bodie et al. (2008)

7.1. Previous research of market efficiency at Nord Pool

It has been conducted numerous analysis which have concluded that the Nord Pool market is not efficient. Ex. Gjolberg and Johnsen (2001) and Herra´iz and Monroy (2009). However, it is worth mentioning that the efficient market hypothesis is rejected for most commodities (Engel, 1996).

Arciniegas et al. (2003) take the analysis one step further and investigate primarily weak market efficiency at Nord Pool and how the market has developed with regards to this. They found that the Nordic electricity futures market satisfies the weak-form efficiency hypothesis and that it has improved in recent years. Although the market is stated to be efficient, it is much less efficient than other commodities in their analysis, i.e. the electricity market has room for improvements.

7.2 Maturity of the market

Arciniegas et al. (2003) state that in new markets, even the most experienced traders may lack sufficient information to know, ex ante, what the profitable trading opportunities ex-post are. This will of course lead to missed arbitrage opportunities. As the market matures, market participants "learn" more about how the market works which allows them to be better prepared to take advantages of arbitrage opportunities. Removal of these arbitrage opportunities leads to higher market efficiency. They also state that the higher the number of participants, the more liquid and efficient can one assume the market to be.

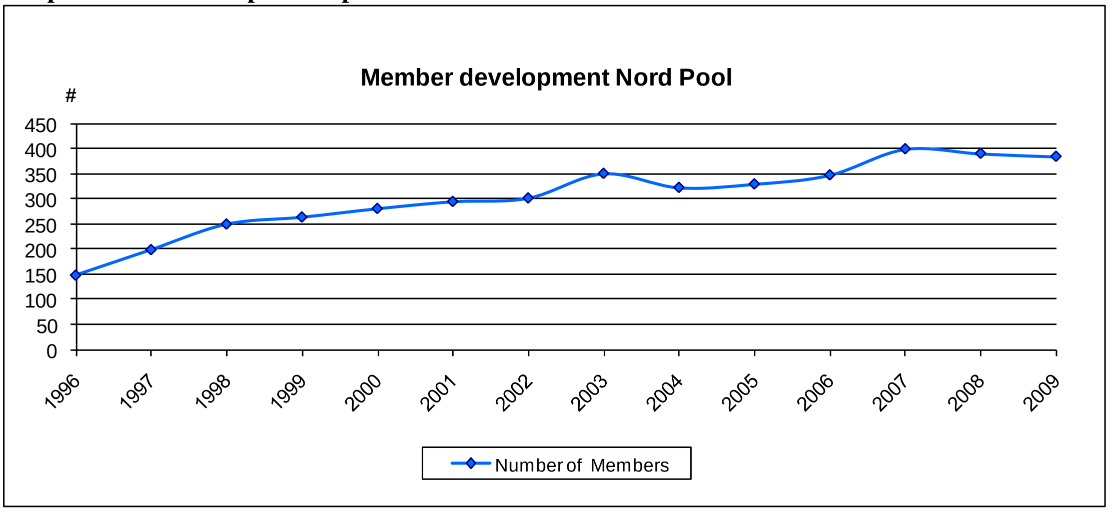
The Nord Pool market is the oldest of its kind and has therefore been an object of wide attention. This interest has probably given the market a steeper learning curve than what could be expected if the market participants were to analyze the market with no outside intrusion. However, its early emergence may also have given the participant a wrong foundation since it was more experimental in the start.

As market participants and liquidity have an impact on market efficiency, the development of these factors is presented below.

7.2.1 Market participants

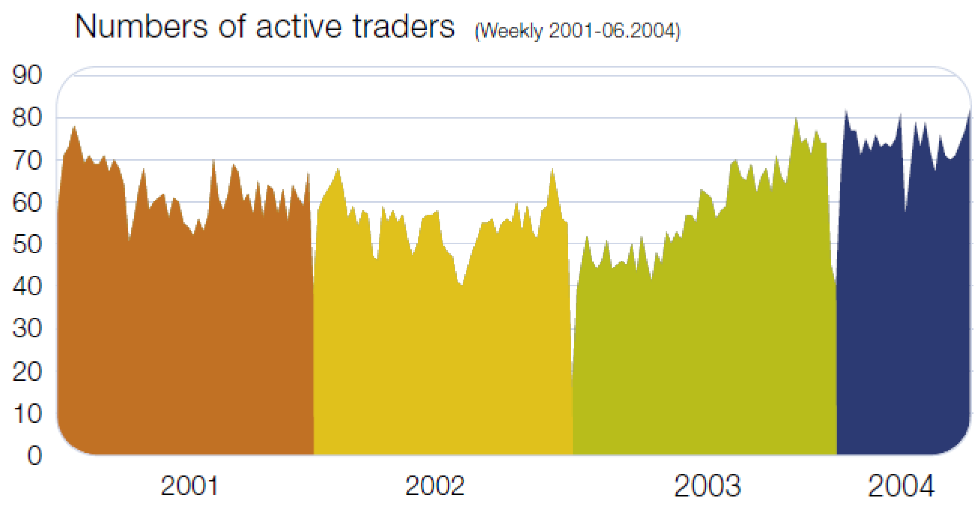
For a market to be efficient it is a necessity that there are many market participants. Graph 16 shows membership development since the Nord Pool exchange opened.

Graph 16 Membership development Nord Pool 1996-2009



It has been a firm increase in members since the opening, with a small decrease after the shock period of 2003 but the exchange recovered shortly after. It was a restructuring of membership alternatives in 2008, which may be a cause for the small decrease seen in 2008. However, membership number alone is not a good indicator for market activity. Figure 7 shows how many weekly active members the exchange had in the time period from 2001 to 2004. Compared to the 300-350 members Nord Pool reported in the same time period, it reveals that many members are not active. Figure 7, presenting number of active traders, gives a more reasonable estimate of the market activity for the period. More updated numbers are not available, but one can assume that there still is a great deal of "silent" members. Level of activity is also very variable throughout the year. This may result in lower efficiency in the market since seasonality in trading activity may compromise the market's possibility to gain knowledge of accurate market characteristics.

Figure 7 Active traders Nord Pool 2001-2004[37] Source Nord pool interim review 1 Jan-30-June 2004

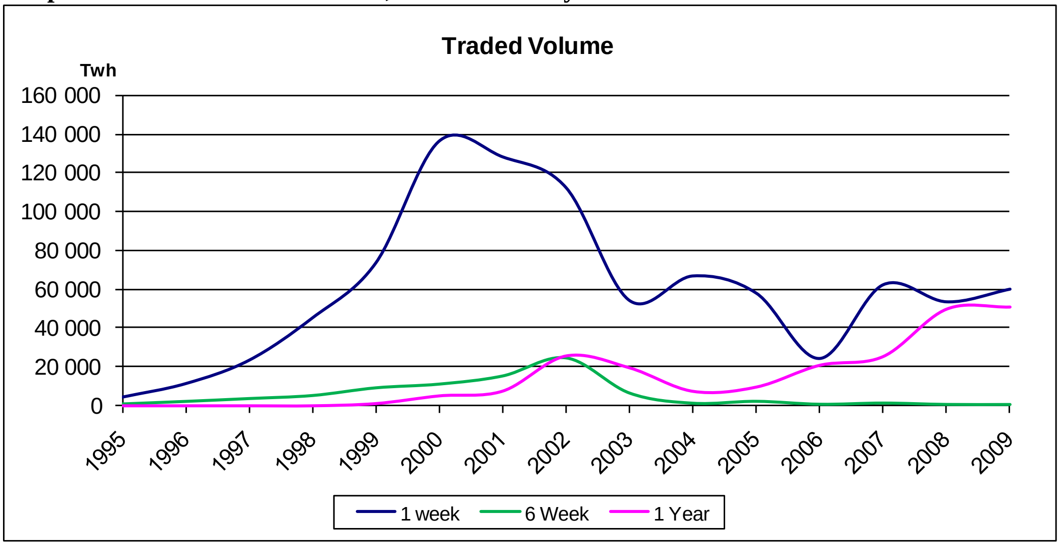


Another important feature is the spread of trading activity among the members. In 2008, 31 members accounted for 80 percent of the total turnover[38]. This is an improvement from earlier years, but the market is still highly influenced by few major companies. This may compromise market efficiency further.

7.2.2 Liquidity

According to Arciniegas et al. (2003) market efficiency is also gained with higher liquidity in the market. Graph 17 shows the historic liquidity for 1 week, 6 week and 1 year contracts.

Graph 17 Traded volumes 1 week, 6 weeks and 1 year contracts



[37] Source: Nord pool interim review 1 Jan-30-June 2004

[38] Nord Pool annual report 2008

Traded volume for the 1 week contracts have fluctuated greatly, with a peak in 2000. The 6 weeks contracts have never been traded in a large extent. It was a temporary increase in traded volume around 2001- 2002, but today, very few 6 weeks contracts are traded. If Arciniegas et al. (2003) are correct with regards to the linkage between market efficiency and liquidity, one can expect the 1 week contracts to exhibit higher efficiency tendencies compared to the 6 weeks contracts.

Botterud et al. (2009) stated that the liquidity for the forward contracts and futures contracts has changed considerably since Nord Pool opened. In the startup face the liquidity was in the shorter term of the market(day ahead and weeks), while in the later stage the liquidity has gone to the longer term products (month ahead, quarter ahead and year ahead). Graph 17 therefore includes liquidity development for 1 year contracts. By comparing 1 year contracts with the 1 week contracts, one can see that Botterud's statement seems to be correct. One possible explanation may be the entrance of more financial speculators in the market and the fact that Nord Pool now is more closely connected to continental Europe.

7.3. Joint hypothesis problem

When testing for market efficiency, one comes across what Fama (1970) called the "joint hypothesis problem". The joint hypothesis problem is that market efficiency can not be rejected without an accompany rejection of the model for market equilibrium (e.g. the price setting mechanism)[39]. If a model yields return significantly different from the market, one can never be certain if the imperfection is in the model or if it is market inefficiency. In chapter 8, the model framework is presented, assumptions/simplifications that are made and an overview of previously tested models.

[39] Internet resource nr: 7

8. Model framework[40]

In energy finance the term “model” is used in two different contexts with different user applications. The first type is “purely probabilistic models”, which are reduced-form models which try to identify a realistic description of the price distribution and trajectories of the price. This can be used for risk management and derivative pricing. Most probabilistic models include a deterministic part and a stochastic part, where the deterministic part includes properties that are clearly identified and truly predictable. The stochastic part represents the randomness of the price dispersion. There are many models that try to identify the special features of electricity with mixed results. As this thesis revolves around the other type of models see alternative sources for more information (ex. Fiorenzani 2006).

The other clashes of models are the econometric models, which test the empirical consistency of a certain economic theories. They are a simplistic representation of what influences the prices in discrete time, and they are used to understand the present price determination and predict future prices. There are different groups of models which can grossly be divided into 3 categories:

1. Autoregressive moving average models (ARMA): the classical econometric framework. It assumes linear relationships between the level of electricity prices at time t (p_t), its lagged values ($p_{t-1}, p_{t-2}, \ldots, p_{t-n}$) and the values (lagged and not) of a set of explanatory variables ($X_{it}, X_{i(t-1)}, \ldots, X_{i(t-k)}$). Together;

   $$P_t = \alpha + \sum_{i=1}^{n} \beta_i P_{t-i} + \sum_{l=1}^{m} \sum_{j=1}^{k} \lambda_{lj} X_{l(t-j)} + \varepsilon_t \text{ where } \varepsilon_t \text{ is an i.i.d process}$$

   i.i.d process implies that the error term has a zero mean and constant conditional and unconditional variance.

   It assumes that the ordinary least squares (OLS) assumptions are met, reviewed in chapter 8.1. This model framework can also be used in maximum likelihood methods, but this is beyond the scope of this thesis.

[40] Theory from Fiorenzani 2006

2. Generalized autoregressive conditional heteroskedasticity models (GARCH): If not all the OLS assumptions are fulfilled, a standard ARMA model can give low explanatory power or compromise the model's ability to make good conclusions. The coefficients are not affected, but the standard errors will be incorrect which gives wrong t-values. The GARCH framework can improve the goodness of the fit and out-of-sample forecasting ability when the error term exhibit heteroskedastic behavior (time varying volatility, see section 5.4). By including variables that will capture the autocorrelation effects in the residuals given by the heteroskedastic behavior the goodness of the fit can be improved.

3. Autoregressive Fractionally Integrated Moving Average (ARFIMA) models: if a time series has long memory, i.e. an extremely slow decay of the empirical autocorrelation between subsequent observations, it will not be identified by standard methods of identifying stationary processes. The ARFIMA model tries to find multiple stationary processes or long term stationary in a time series that is not found using ordinary methods. By using an ARFIMA framework, some time series which were exempted from the analysis due to problems with non-stationarity can be included in the analysis.

Although electricity prices exhibit time varying volatility and long memory[41] many analysts use mainly ARMA methods in analyzing electricity markets because the complexity of the last two groups of models is much higher, and not as well known as the first. It is also worth mentioning that the increased complexity should be compensated by a sensible increase in the model's explanatory power. This thesis main focus is therefore on the models which has an ARMA foundation.

[41] Haldrup and Nielsen (2005)

8.1 OLS Assumptions[42]

The analysis is based on the ordinary least square (OLS) technique, where one tries to identify linear relationships between the stated variables. In order to use this technique there are some assumptions that needs to be fulfilled.

8.1.1 Assumptions about the residuals

- $E(\varepsilon)= 0$, ex ante is the expected value of the residuals zero
- Var (ε)= constant, the time series are homoscedastic, i.e. exhibits constant variance. As discussed in section5.4 this is a problem for the electricity prices. It could be solved by implementing GARH framework as mention earlier. However, this problem is ignored in this thesis.
- $Cov(\varepsilon_i, \varepsilon_j)=0$, no auto correlations in the residuals. Including lags of the explanatory variable can reduce the presence of autocorrelations. The Durbin–Watson (DW) statistic identifies autocorrelations. A DW statistic of 2 indicates no autocorrelations.
- ε~N, the residuals are normal distributed.

8.1.2 Special assumptions for time series data i.e. stationary process

In order to test for long term price relationships it is a necessity that the variables are stationary. This means that the results are the same regardless of the time period used. To get an indicator if a variable is stationary one can plot the data series against its means. If the variable tends to cross its means often it can be stationary. Otherwise one can conduct a Dickey-Fuller (DF) test. Time lags can be included if the time series exhibits serial correlation. If lags are included one use an Augmented Dickey-Fuller (ADF) test[43].

$$\Delta p_t = \alpha - \beta p_{t-1} + \gamma \Delta p_{t-2} + .. + \gamma \Delta p_{t-n} + \varepsilon_t$$

H_0; $\beta=0$; time series is not-stationary ; H_1; $\beta \neq 0$; time series is stationary

[42] lecture notes Empirical analyses of financial market FIE xxx

[43] One can also include, trends and seasonality if the time series exhibits such.

If a price series is stationary it is classified as I(0). The time series needs to be stationary in order to use it in a regression analysis, otherwise one can get spurious results. If the time series is not stationary, one-time differentiates usually makes it so. The series will then be I(1). However, if one differentiates the series the analysis will go from looking at long term relationship to short term relationship. To overcome this problem one can check if there is a linear combination between two I(1) variables that is i(0), i.e. stationary. If this exist the variables are said to be co-intergraded (there is a long term equilibrium between the two which they will gravitate). If this is the case it is possible to use the price data in the regression.

An ADF test is conducted for both the absolute values and the differentiated series for all time periods and series. The results are presented in table 7.

Table 7 Augmentet dickey fuller test for stationarity

		Full sample	1995-2000	2000-2005	2005-2010
Spot	Absolute	-3.281*	-1,966	-3,346*	-2,246
	Log	-24,38**	-13.04**	-16,00**	-12,76**
1W	Absolute	-3.903**	-1,816	-3,922**	-2,564
	Log	-25,66**	-12,58**	-16,22**	-15,30**
2W	Absolute	-3.301*	-1,733	-3,160*	-2,352
	Log	-25,05**	-12,74**	-15,74**	-14,72**
3W	Absolute	-2.961*	-1,56	-3,171*	-2,328
	Log	-24,83**	-12,71**	-14,68**	-15,41**
4W	Absolute	-2.994*	-1,471	-3,185*	-2,278
	Log	-24,61**	-12,84**	-14,55**	-15,13**
5W	Absolute	-2.907*	-1,489	-3,233*	-2,13
	Log	-25,23**	-14,46**	-14,87**	-14,50**
6W	Absolute	-2.986*	-1,318	-3,253*	-2,234
	Log	-25,24**	-12,77**	-14,46**	-16,08**

* Significant on the 5% level ** significant on the 1% level (the darker blue had to include one lag to be significant)

All tests are significant for the full sample and for the period 2000-2005, one can therefore state that these parts of the series are stationary. In other periods, the time series are I(1).

One can use an unrestricted method to check if the spot and future price are co-intergraded in the first and third period, and therefore can be used in the analysis.

$$p_t^s = \beta p_t^F + \varepsilon_t \rightarrow \hat{\varepsilon}_t = [p_t^s - \hat{\beta} P_t^f]$$

p_t^s = Spot price at time t

P_t^f = Forward price at time t

If $\hat{\varepsilon}_t$ is stationary, the spot and forward price are co-intergraded i.e. it is a long-run equilibrium between the two price series

Table 8 ADF test for co-integration between spot and future prices

	1995-2000	2005-2010
1W	-11,05**	-14,33**
2W	-7,833**	-11,87**
3W	-6,232**	-8,945**
4W	-5,473**	-7,951**
5W	-4,928**	-6,475**
6W	-4,453**	-6,081**

* Significant on the 5% level ** significant on the 1% level

The "true" critical value for the variable is higher than a standard t-value, because the variable is biased. However, all values are in such a magnitude that this issue is probably not essential.

OLS assumptions are therefore meet for all variables in this analysis, and inclusions of them in the regression would give trustworthy results.

8.2 Acknowledged models

The objective of this empirical analysis is not to propose formal models of the price expectations, but rather to use descriptive statistics and simple regression analysis to investigate to what extent easy observable variables can contribute to explain the historical observed market efficiency at Nord pool and identify changes in this aspect. As there are infinite numbers of variables that can have some explanatory power for this relationship, this analysis is limited to model framework already defined by academics. The main focus is to use already accepted models to illustrate market efficiency and how it has changed as the market has matured.

Fama and French (1987) were some of the first to conduct major empirical study of relationships in commodity markets. They focused specially on the forecasting power the forward prices had on the following spot prices. They introduced the term basis (difference between futures and today's spot price) and claimed this to be the sum of expected risk premium and expected change in spot prices:

$$F_{t,T} - S_t = E_t(P_{t,T}) + E_t[S_{t+i} - S_t],$$

where the expected premium is defined as

$$E_t(P_{t,T}) = F_{t,T} - E_t(S_{t+i})$$

From this they defined a model for the basis predicative power on the future spot price.

$$S_T - S_t = \alpha + \beta_1[F_{t,T} - S_t] + \varepsilon_{(t+T)}$$, Fama and French (1987) model 1

if β(1) is significant it indicates that the basis observed at time t contains information about the change in the spot price from time t to time T. The future price has power to forecast the change in the spot price. The more this relationship explains of variance in the spot price changes the more efficient can the market be stated to be.

They also defined a model to identify time varying risk premium:

$$F_{t,T} - S_T = \alpha + \beta_2[F_{t,T} - S_t] + \varepsilon_{(t+T)}$$, Fama and French (1987) model 2

Significant β(2) means that the basis observed at time t contains information about the premium to be realized at time T.

Gjolberg and Johnsen (2001) (Analysis period Oct 95-Jan01 2000) use Farma and Fench (1987) model 1 as a base for their investigation of the Nord pool market. They found that the basis is a relatively poor predictor of subsequent spot price changes, measured by the explained variance (R2). In order to further test market efficiency they extend the model with a set of simple variables that are easy available. Their main model is as follow:

$$S_T - S_t = \alpha + \beta_1[F_{t,T} - S_t] + \beta_2 S_t + \beta_3[F_{T,t-T} - S_t] + \beta_{4-16}\text{Season} + \varepsilon_{(t+T)}$$

where

- S_t = Average spot price level within week t. If significant it would indicate that there is information in today's price level that can be utilized in order to improve the forecast of the subsequent change in spot price not captured in the basis.
- $[F_{T,t-T} - S_t]$ = forecasting error. If it is significant it would indicate that the error observed in the last periods has an influence in the changes of spot prices that are not captured in the basis. The market does not adjust their estimates to errors made in the previous periods.

Season represents monthly dummies. If significant they may suggest that there is observable information (which month "t" is in) at time t that can be used to improve the basis forecast. In this thesis, the model is further simplified by changing season dummies to a summer/winter dummy. The reason for this is that Gjolberg and Johnsen (2001) only found significant seasonal variations for the month of January, and as this analysis already has established that there is a reduction of clear seasonal patterns in the market in the recent time. The final model is;

$$S_T - S_t = \alpha + \beta_1[F_{t,T} - S_t] + \beta_2 S_t + \beta_3[F_{T,t-T} - S_t] + \beta_4 Summer + \varepsilon_{(t+T)}$$

In the following, Farma and Fench (1987) model 1 and Gjolberg and Johnsen (2001) extensions is used as a basis to analyze the development of market efficiency at Nord Pool.

9. Market efficiency at Nord Pool

The models defined under section 8 are used in this chapter to analyze market efficiency at Nord Pool. The main idea and simplifications made in this analysis follow that of Gjolberg and Johnsen (2001)

9.1 Model 1

In this section, Farma and Fench (1987) model 1 framework is used to test if the basis is a good predictor of subsequent spot price changes, measured by explained variance (R2). If the explained variance is high one can state that the efficiency in the market is good and the basis is a good predictor of subsequent spot price changes. A significant β represent a predictive power in the basis for following spot price changes.

$$S_T - S_t = \alpha + \beta_1 [F_{t,T} - S_t] + \varepsilon_{(t+T)}$$

Table 9 presents the results of the analysis for all periods and contracts. All betas except the ones for the second period, 3-6 weeks contracts, are significantly different from zero, indicating that the basis has some prediction power for spot price changes. The value of the beta coefficient varies greatly between the different periods and contracts. For 1 week contracts in the last period the coefficient is 0,91. The interpretation of this number is that historically over the period one could multiply the observed basis with this beta coefficient and explain 48% of the observed changes in the spot price for one week contracts. In the same sub period, one can also find the lowest (significant) coefficient of the sample in the 6 weeks contract (0,33). This contributes less to explaining the observed variance in the spot price than in the other example with only 3,99% of the variance explained. This is in line with what is expected due to the liquidity effects ref. section 7.2.2.

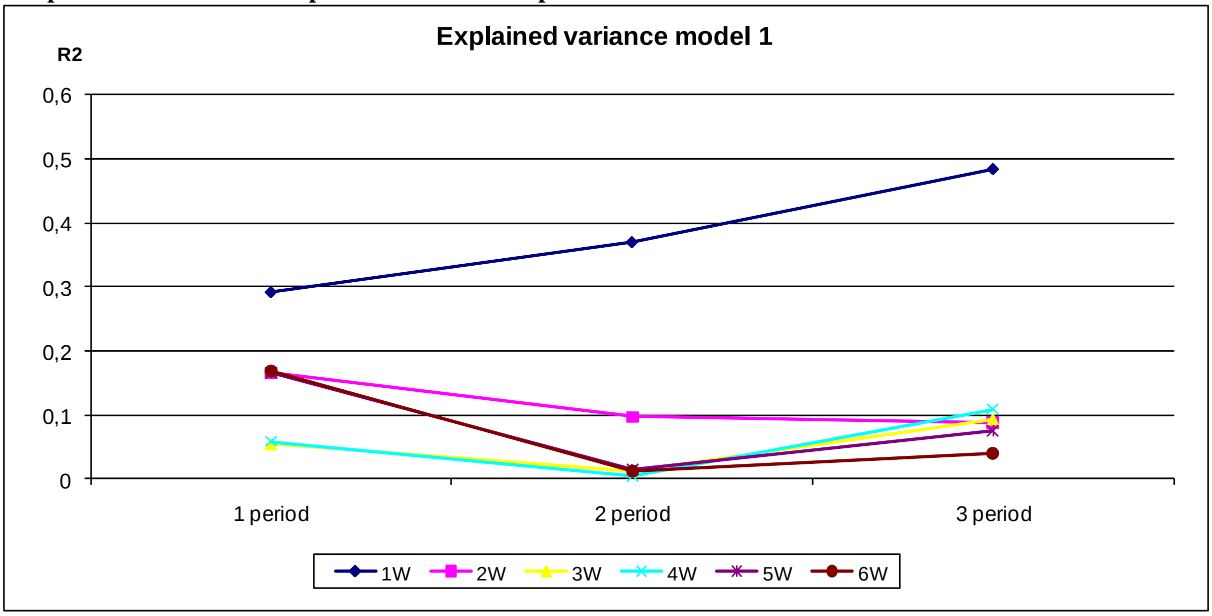
Table 9 Regression results model 1

	1W	2W	3W	4W	5W	6W
	Full sample					
Constant	-2.63718	-3.8782	-3.76357	-4.39328	-4.93333	-4.19088
	[-3.35**]	[-2.6**]	[-2.06*]	[-2.13*]	[-2.1*]	[-1.63]
basis	0.762746	0.521079	0.39728	0.409666	0.420798	0.363167
	[21.7**]	[8.96**]	[6.47**]	[6.72**]	[6.55**]	[5.43**]
R2	0.393077	0.0994642	0.05459	0.0587071	0.0559095	0.0391494
	1 Period					
Constant	-0.953556	-1.99333	-2.62795	-3.59347	-4.48327	-5.36712
	[-1.12]	[-1.47]	[-1.56]	[-1.9]	[-2.18*]	[-2.44*]
basis	0.780831	0.606691	0.524567	0.566513	0.565471	0.559371
	[10.1**]	[6.96**]	[6.01**]	[6.67**]	[6.96**]	[7,00**]
R2	0.292241	0.164905	0.129117	0.154853	0.166612	0.0391494
	2 Period					
Constant	-3.80649	-4.75559	-1.90651	-0.724412	-2.39866	-1.47394
	[-2.02*]	[-1.37]	[-0.466]	[-0.159]	[-0.457]	[-0.261]
basis	0.693232	0.525001	0.224381	0.141489	0.29866	0.302608
	[11.5**]	[4.9**]	[1.73]	[1.02]	[1.85]	[1.66]
R2	0.369632	0.0969291	0.0131727	0.00465617	0.0150158	0.0391494
	3 Period					
Constant	-3.53694	-5.068	-6.86368	-8.1754	-7.37223	-5.01546
	[-2.79**]	[-1.83]	[-1.94]	[-2.03*]	[-1.59]	[-0.968]
basis	0.905773	0.512791	0.502981	0.525886	0.442684	0.32844
	[15.4**]	[4.95**]	[5.1**]	[5.58**]	[4.52**]	[3.25**]
R2	0.482752	0.0878936	0.0927519	0.109083	0.0745787	0.0399498

* Significant on the 5% level ** significant on the 1% level

For the purpose of this analysis, explained variance (R2) is the most important variable. If one can include easy available explanatory variables and increase the R2, the market can be said to be not-efficient, see the reasoning from Gjolberg and Johnsen (2001). An alternative interpretation is as mentioned under chapter 7.1. The model is not sufficient to explain the pricing mechanism in the market. It has been many analyses which have concluded that the Nord Pool market is inefficient. This thesis therefore assumes that the market is inefficient and investigates if the market has exhibited some changes which may indicate improved efficiency as it matures. Graph 18 plots the R2 development of the first model

Graph 18 Historical development of model 1 explained variance



From graph 18 one can see that the model's forecasting power for the 1 week contract has increased considerable as the market has matured. The other contracts on the other hand experienced the opposite reaction to time, with a decreased explanatory power as time went by. For the 6 weeks contract there were little changes between the sample periods. This is not surprising since there has been a decrease in liquidity for contracts of this length.

9.2 Model 2

This section is based on Gjolberg and Johnsen (2001) model:

$$S_T - S_t = \alpha + \beta_1[F_{t,T} - S_t] + \beta_2 S_t + \beta_3[F_{T,t-T} - S_t] + \beta_4 Summer + \varepsilon_{(t+T)}$$

None of the summer dummies were significant, the analysis was therefore done again without seasonal dummies. The final model used is therefore;

$$S_T - S_t = \alpha + \beta_1[F_{t,T} - S_t] + \beta_2 S_t + \beta_3[F_{T,t-T} - S_t] + \varepsilon_{(t+T)}$$

The results are presented in table 10. Most betas are significantly different from zero. Beta$_3$ represents the market adjustment to error made in previous periods. If it is significant it could indicate that the market participants do not take previous errors into consideration when they make new estimates for the correct price to purchase forward contracts.

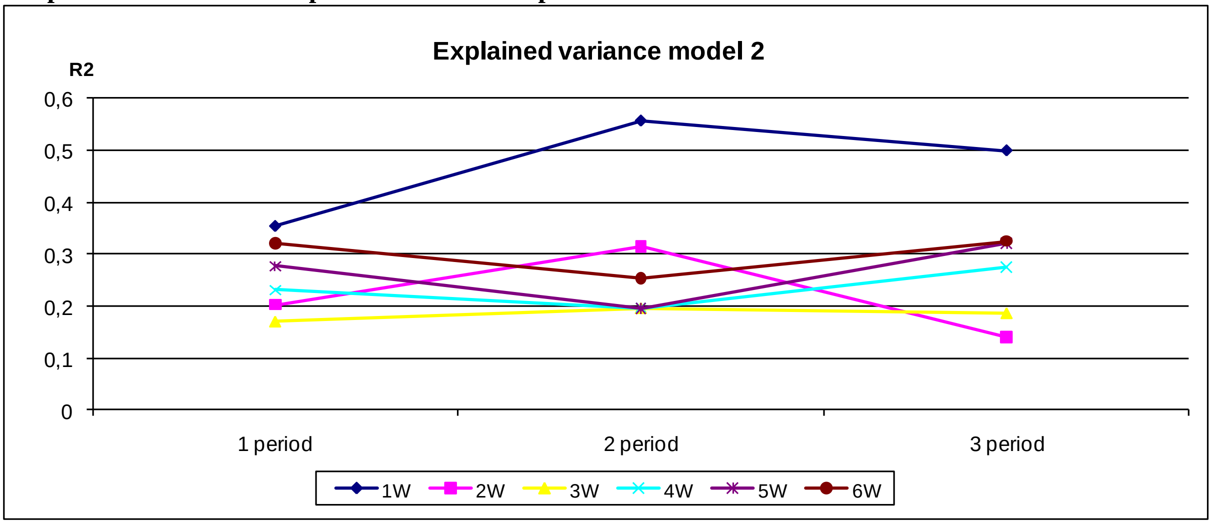
Table 10 Regression results model 2

	1W	2W	3W	4W	5W	6W
			Full sample			
Constant	8.117	16.880	22.579	28.488	36.623	43.604
	[4.83**]	[5.35**]	[6.01**]	[6.78**]	[7.72**]	[8.3**]
Basis	0.748	0.600	0.559	0.584	0.610	0.553
	[22**]	[10.1**]	[8.7**]	[9.42**]	[9.49**]	[8.24**]
Spot	-0.044	-0.096	-0.121	-0.150	-0.189	-0.216
	[-6.38**]	[-7.5**]	[-7.92**]	[-8.83**]	[-9.87**]	[-10.2**]
Error	-0.235	0.038	-0.097	-0.138	-0.152	-0.159
	[-6.75**]	[1.07]	[-2.73**]	[-3.94**]	[-4.35**]	[-4.52**]
R2	0.469	0.167	0.134	0.160	0.178	0.169
			1 Period			
Constant	3.544	6.647	9.127	12.216	15.370	18.926
	[1.82]	[2.1*]	[2.36*]	[2.89**]	[3.37**]	[3.91**]
Basis	0.885	0.685	0.521	0.632	0.697	0.735
	[11.3**]	[7.02**]	[5.16**]	[6.6**]	[7.82**]	[8.72**]
Spot	-0.029	-0.059	-0.084	-0.114	-0.139	-0.167
	[-2.37*]	[-2.98**]	[-3.51**]	[-4.36**]	[-4.94**]	[-5.6**]
Error	-0.262	-0.132	-0.042	-0.136	-0.239	-0.310
	[-4.13**]	[-1.91]	[-0.594]	[-1.95]	[-3.56**]	[-4.84**]
R2	0.354	0.203	0.170	0.231	0.277	0.321
			2 Period			
Constant	25.923	54.243	60.175	60.175	68.916	85.698
	[5.67**]	[6.77**]	[6.33**]	[6.33**]	[6.61**]	[7.42**]
Basis	0.743	0.805	0.642	0.642	0.557	0.726
	[12.7**]	[7.88**]	[4.88**]	[4.88**]	[4.06**]	[4.83**]
Spot	-0.128	-0.283	-0.296	-0.296	-0.334	-0.420
	[-6.29**]	[-8.1**]	[-7.05**]	[-7.05**]	[-7.24**]	[-8.38**]
Error	-0.233	0.125	-0.107	-0.107	-0.087	-0.044
	[-3.76**]	[2.2*]	[-1.87]	[-1.87]	[-1.55]	[-0.77]
R2	0.556	0.315	0.197	0.197	0.196	0.253
			3 Period			
Constant	7.293	24.749	40.606	59.003	84.061	108.724
	[1.81]	[3.09**]	[4.12**]	[5.42**]	[7.12**]	[8.34**]
Basis	0.887	0.552	0.611	0.720	0.697	0.585
	[14.8**]	[5.15**]	[5.89**]	[7.52**]	[7.49**]	[6.28**]
Spot	-0.034	-0.097	-0.152	-0.213	-0.291	-0.362
	[-2.77**]	[-3.94**]	[-5.07**]	[-6.46**]	[-8.08**]	[-9.11**]
Error	-0.055	-0.058	-0.171	-0.322	-0.400	-0.404
	[-0.864]	[-0.93]	[-2.66**]	[-5.19**]	[-6.89**]	[-7.21**]
R2	0.499	0.141	0.187	0.275	0.322	0.326

* Significant on the 5% level ** significant on the 1% level

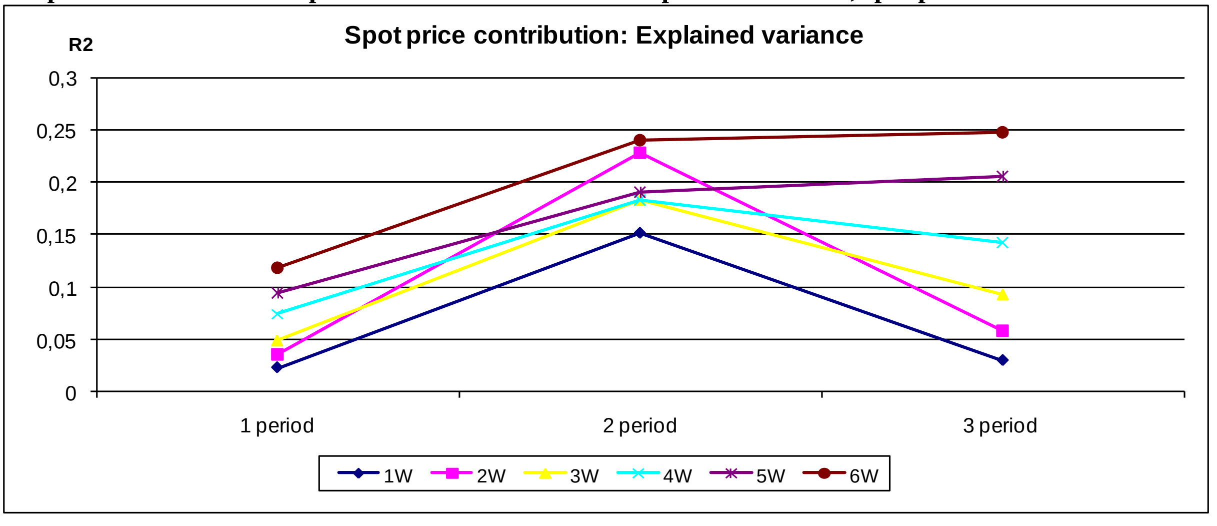
The spot price variable is highly significant for all contracts and periods, indicating that the market participants do not take spot price levels into consideration for their estimations. They can improve their estimates by including spot price levels. If this is done, efficiency could be improved. The beta coefficients are all negative, implying that at high price levels the basis tends to overshoot the subsequent change in spot price. Graph 19 illustrates the development of the model explained variance. For the one week and two weeks contracts there was at first an increase in explanatory power from the first to the second period, before a decrease in the third period. For the other contracts there was first a decrease followed by an increase. Again it is just for the 1 week contract there has been a substantial improvement.

Graph 19 Historical development of model 2 explained variance



The explained variance in the model is highly influenced by the basis. A separation of the contribution for each variable for the explanatory power is presented in graph 20 and 21. For the extra variables beyond the basis, contribution of R2 should be as low as possible. If it is high the market can improve their estimates by including these easy available variables in pricing estimates for the forward contracts. The increased value of additional information would then have been captured by the basis.

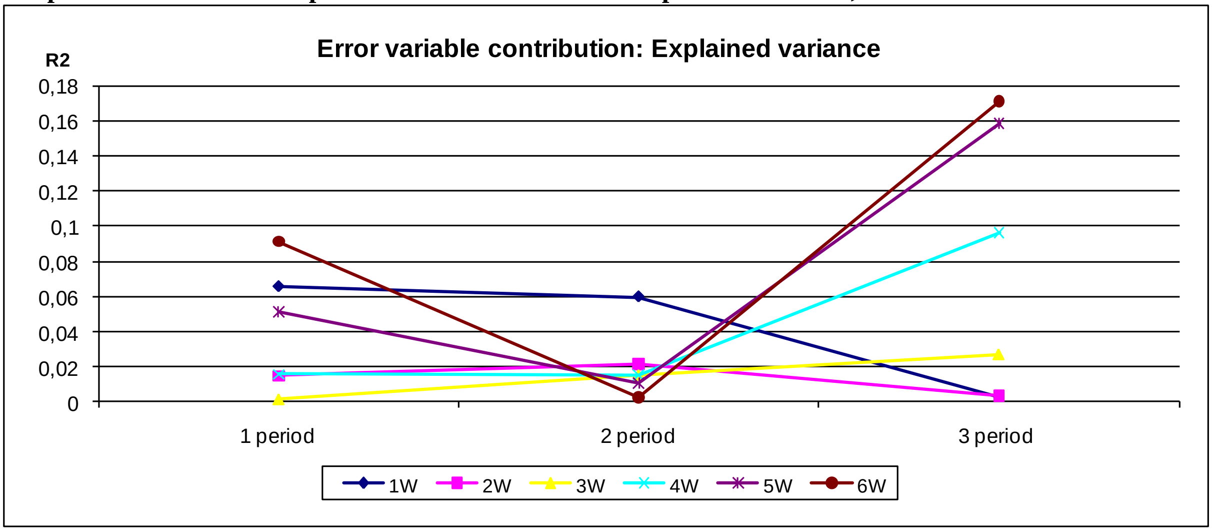
Graph 20 Historical development of the contribution in explained variance, spot price



The spot price levels contribution to R2 has changed considerable for the 5 and 6 week contracts over the period and has doubled from the first period to the last period. There seems to be a permanent shift in how the market incorporates spot price levels. For the one and two week contracts, the level in the third period is approximately the same as in the first period. They had a sharp increase in the second period, indicating only a temporary decrement for the market's ability to incorporate this information in contracts with this length.

This is also correct for the error variable. Graph 21 shows the development of the R2 contribution from this variable. For the longer-end contracts there is a clear increase in the R2 for the error variable. For the short end contracts, the error variable explanatory power is reduced to almost nothing in the last period, see graph 21. As previously mentioned, not all the beta values are significant for this variable. The R2 therefore only has some degree of trustworthiness. However, it is a clear tendency that the errors exhibited in the longer-end contracts have more and more explanatory power for the spot price changes which is not captured by the basis. This can be a result of the market's lack of trading in contracts with this length. For the 1 week and 2 weeks contract the R2 contribution has almost disappeared in the last period, indicating that error made in the previous period are incorporated in the basis and hens the participant's price estimates.

Graph 21 Historical development of the contribution in explained variance, error variable



These simple extensions gave a significant increase in explained variance compared to the Farma and Fench (1987) model 1. This increase in total explained variance by incorporating easy available information further indicates market inefficiency. The conclusion made by Gjolberg and Johnsen (2001) still holds. It is only for the one week contract the market exhibits a clear increase in efficiency. For the other contracts market maturity and increased efficiency is not that clear. This could be a result of the lack of trading in contracts with these particular lengths to delivery or other market fundamentals.

10 Concluding remarks

The purpose of this thesis has been two folded. The first part was an analysis of electricity prices at Nord Pool, and the second part was an assessment of market efficiency and how this has changed since the exchange opened.

The special characteristics of electricity give Nord Pool very interesting challenges. Its early emergence and long history have resulted in many researchers taking an interest in the market, which may have given the market a steeper learning curve.

The analysis period was from 1996-2009, i.e. a period of 14 years. Although this could be considered to be a long period for analysis purposes, the market has undergone major changes since the exchange opened, so early data are probably not representative for the situation today. Despite this, inclusion of the data is important due to the fact it could reveal increased efficiency as the market has grown and learned

It is quite clear that there have been a shift in the prices after 2005. There are many market conditions that could be the cause of this. It has been an increase in demand without any considerable addition of production capacity, which seems to have shifted the demand to a higher and steeper portion of the supply curve, giving higher and more volatile prices. Introduction of EU ETS, emission scheme in 2005 have changed the cost structure of production and consequently the overall market conditions for production systems. Change of base currency to EUR in the same year has also introduced a currency risk and currency influence to the price. A deeper analysis of how this has impacted the prices and price development at Nord Pool would have been of great interest.

The other alternative for this apparent shift in electricity prices may be caused by changed market efficiency. In contracts with high liquidity, the market exhibits efficiency improvements. However, liquidity for the 2-6 weeks contracts has been low and stable for the whole period, i.e. no major efficiency improvements. An extended analysis based on contract with longer contract length than 1-6 weeks would be of interest. It may show higher market efficiency improvement since there has bee a positive shift in liquidity for these products.

To answer the main question of this thesis with a single cause is difficult or may even be impossible, but it is apparent that Nord Pool has entered a new era. How the market will end up only time will show. One thing are at least certain, the complexity will just continue to increase as Nord Pool gets more and more interconnected with continental Europe and the rest of the World.

IX Overview graphs, tables and figures

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