

Does Size matter?

-

The Effect of Market Integration on Wholesale Prices in the Nordic Electricity Market

Abstract:

The purpose of this paper is to examine the integration of electricity markets in Sweden, Norway and Finland into a single Nordic market between 1996 and 2004. The paper seeks to observe the effect of integration on the development of wholesale prices on the Nordic spot market- Elspot. The tool employed is a regression analysis that includes the main supply and demand determinants of wholesale prices and a proxy for the degree of market integration. We find that market integration has an effect on wholesale prices on the Nordic markets – size matters! Increasing integration leads to a decrease in prices due to efficiency gains. The most probable drivers behind these gains are the diversification of the generation technology portfolio and the reduction of transaction costs. As an additional result, concentration in adjustable generation capacity has been shown to have a significant impact on wholesale prices. The thesis provides policy implications for both the Nordics and Europe, as well as highlights the areas where further research could be beneficial.

Key words: Market Integration, Electricity, Elspot, Nord Pool, Wholesale Price

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1 Introduction

Since the introduction of the EU electricity market directive in 1999¹, Europe has been making strident advances towards a single market for electricity. The Nordic markets were some of the first to begin the path of reform towards more liberal and competitive markets.

The goals of reform where several fold- lower prices; choice for the consumer; increased competition through new entrants to the market; more efficient generation and transmission of electricity; and more security in the supply of electricity.² The Nordics have moved from electricity markets characterized by over-regulation, and a quasi-monopolistic structure, to markets where prices are determined by supply and demand and competitive pressures, in an oligopolistic setting. This transition has been driven by the integration of the national markets of Norway, Sweden, Finland, and Denmark. The Nordic electricity market is seen as exemplary in terms of the benefits to consumers and generators alike.³ It therefore could be the model on which European electricity market integration is premised. In order to examine the veracity of these beliefs this thesis evaluates whether there is a perceivable effect of market integration on the wholesale price levels.

The purpose of this paper is to answer the research question:

What is the effect of market integration on wholesale prices on the Nordic electricity market?

The relevant product for our analysis is electricity, a homogenous good which is not storable.⁴ The relevant market is the Nordic electricity exchange- Nord Pool.

Our goal is to examine the integration of Sweden, Norway and Finland into Nord Pool over time and observe the effect on wholesale prices.⁵ We answer the research question by using a regression analysis that includes the main determinants of wholesale prices and a proxy for the degree of market integration.

Our paper is of importance not only due to the direction of research, but also due to the distinctive nature of the methodology. To our knowledge, there is currently no research published which seeks to establish a relationship between integration of electricity markets and wholesale price fluctuations on a common exchange. In this manner our research is innovative. In addition, our methodology is distinctive as we analyse integration as a “natural experiment” in our methodology. This enables us to isolate integration from other variables in the economic environment of the Nord Pool market and study the effects of this change as if it were an experiment; that is, by assuming that every other exogenous input is held constant, or accounted for. Our methodology also combines approaches in studies of different geographic markets although we draw on experiences that are pre-dominantly pan-Nordic.

The remainder of this document is structured as follows. We examine the evolution of the market and the workings of Nord Pool. This is followed by a presentation of relevant literature on methodology used in evaluating aspects of electricity markets. Subsequently, we

¹ EU Electricity Directive 96/92/EC

² See Joskow (2003)

³ See Woo et al. (2003)

⁴ The latter characteristic as pointed out by Arciniegas et. al (2003), implies that electricity today and tomorrow are different commodities.

⁵ Nord Pool includes Sweden, Norway, Finland, Denmark and Iceland. The latter two are not included in the analysis for reasons presented in the limitations section.

will develop our hypothesis on the relationship between market integration and the development of wholesale prices. Next follows our empirical analysis and results. The paper ends with a discussion of our findings, conclusions and suggestions for further research.

2 Nordic Market: A Descriptive Review

Since the beginning of the last decade the Nordic electricity markets have undergone a gradual transformation from separate national markets to an integrated one. In the first part of this descriptive review, we present the history of integration of the Nordic electricity market and features of the Nordic generation technology portfolio. In the second part, we focus on the Nord Pool spot market, and its pricing mechanisms.

2.1 The History of Integration

Market integration and deregulation of the Nordic electricity markets has had as its objective the replacement of markets based on corporate and national autarky⁶ with a liberalized, expanded market based on trade. The more specific goals of electricity market liberalization included smoothening of price differentials between areas; increasing the efficiency of both production and distribution of electric power; securing efficient building of new production capacity, improving market transparency and lowering prices for the consumer.⁷

The first step in the process was to break up the national electricity monopolies into functions that should be faced with competitive pressures, namely generation and sales, and those that should be maintained as regulated natural monopolies, namely transmission and distribution.⁸ Prior to reform, wholesale electricity prices were substantially different between regions. In 1989, the highest price was two and a half times the lowest price across the Nordic area.⁹ The difference in price indicated that there were inefficiencies in the distribution of electricity, or that the market allowed for strategic behaviour among electricity companies. The discrepancy in prices also caused unbalanced choices in capacity investments, since areas with high-prices received the bulk of the projects.¹⁰

The next step in the integration of the Nordic market was the creation of a wholesale electricity market. The benefits of a common market were the ability to balance supply and demand on a real-time basis and the capability of responding quickly to unplanned outages of generation or transmission facilities.

The Norwegian transmission system operator (TSO) Statnett established the Statnett Marked in Norway in 1993, as a national wholesale market and developed the mechanisms upon which the current Nordic power exchange operates. It was renamed Nord Pool in 1996 when it became a common Norwegian-Swedish market, and the Swedish TSO, Svenska Kraftnät, stepped in as co-owner.

⁶ See Damsgaard and Green (2005)

⁷ See Joskow (2003), and Pierce (2005)

⁸ Separation of the function eliminates the ability of, and the incentive for owners of transmission lines and other natural monopoly facilities to favour their own generation and to handicap their competitors in the retail markets. See Pierce (1986)

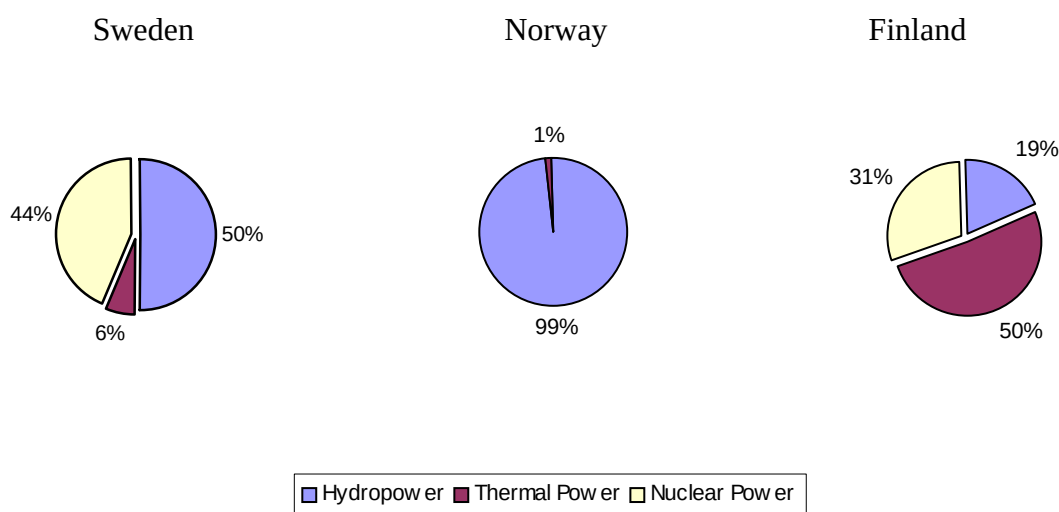
⁹ See Danish Competition Authority (2003)

¹⁰ See Ibid.

Thus, Nord Pool became the first international commodity exchange for trading electric power. Finland joined the Nord Pool Exchange on 15 June 1998. The western part of Denmark has been part of Nord Pool since 1 July 1999. Integration of the rest of Denmark occurred in 2000. Iceland has not yet been fully integrated into Nord Pool.

The integration of the national markets into a common one has impacted the portfolio of generation technologies. Electric production differs considerably among Nordic countries. In Norway, nearly all electricity is generated from hydropower (99%). Power generation in Sweden and Finland is diverse, consisting of hydropower, nuclear, and fossil-fuel power. However, Sweden has far more capacity in hydropower than thermal power¹¹, in comparison to Finland, where the situation is reversed.

Graph 1: Generation portfolio per country in 2001



Source: Danish Competition Authority (2003)

2.2 Nord Pool: The Spot Market

The Nordic electric power market's most relevant feature for this paper is Nord Pool, which operates several marketplaces and market services.¹² We focus in particular on the Nord Pool spot market- Elspot¹³. This is the physical market where a steadily increasing proportion of power trade is taking place as shown in Graph 2.

On the Nord Pool Spot market participants trade power contracts for next-day physical delivery at the Elspot market. Trading is based on an auction trade system. The spot concept is based on electronic bids for purchase and sale of power contracts of one-hour duration that cover all 24 hours of the next day.¹⁴ After the noon deadline on the day before trade, participants' bids comprise the entire buy and sell orders for the next day.¹⁵ These orders

¹¹ Thermal power plants burn several types of fuels, including gas, coal, peat, and wood.

¹² There is a spot market called Elspot (Nord Pool Spot AS), a financial derivatives market for futures, forward and option contracts, and clearing services for financial electricity contracts (Nord Pool Clearing ASA).

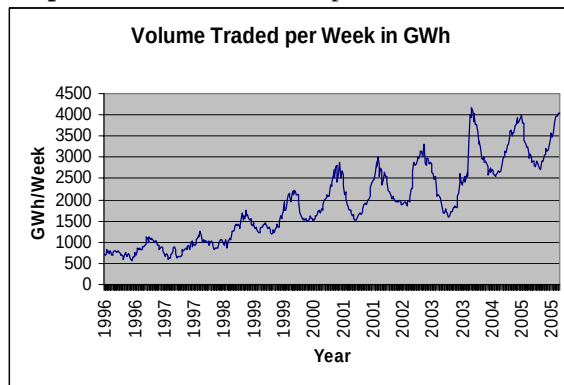
¹³ http://www.nordpoolspot.com/trading/The_Elspot_market/

¹⁴ These markets are referred to as the day-ahead markets.

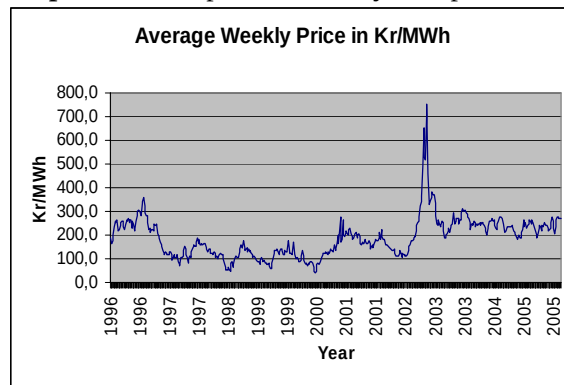
¹⁵ The market is divided several bidding areas. Sweden and Finland are each one area. Norway is split into five areas and Denmark into two.

create aggregate demand and supply curves for each hour block of power delivery. The spot price for each hour is determined by the intersection of the curves. This spot price is known as the system price. It is also denoted as "the unconstrained market clearing price"¹⁶ since the system price balances sales and purchases in the exchange area, ignoring transmission constraints. Assuming no congestion between different areas, there will be only one price for the whole Nordic market- the system price, which is the focus of the thesis. Graphs 2 and 3 below show the evolution of volume traded and price between 1996 and 2005.

Graph 2: Turnover on the Spot market



Graph 3: Development of the system price



Source: Nord Pool

At the Elspot, there is a distinction between the system price and area prices. Whenever transmission constraints arise, the integrated market is separated into two different price areas- a surplus and a deficit area.¹⁷ Nord Pool regulates area prices to ensure that electricity flows from energy surplus regions to the energy deficit regions after observing the demand and supply data for the various price areas. This ensures security of electricity supply and effectively equalizes prices across price areas.

Having reviewed the history, dynamics, and essential features of the Elspot market, we now turn to relevant literature on modeling electricity markets that has guided our thoughts on methodology.

3 Relevant Literature on Methodology

We review the literature on the potential factors effecting price developments in the Nordics. This will provide an understanding of what has directed our methodology and empirical strategy. Since we are interested in the price setting dynamics of the Nordic market, we investigate the factors that affect the demand and supply curves. We also draw lessons from research on the electricity markets in England and Wales.

3.1 Modelling the Nordic Electricity Market

As the Nordic power market is dominated by hydro generation, one crucial factor in the determination of electricity price on the market is water availability. Although electricity is a non-storable commodity, water is storable in hydropower reservoirs.

¹⁶ http://www.nordpoolspot.com/trading/The_Elspot_market/

¹⁷ In reality, of course, more than one area may suffer from grid congestion so that there are more than two area prices.

Beginning our discussion with hydropower in the Nordics, Gjolberg and Johnsen (2001) analyse monthly prices between October 1995 and January 2001. The paper models the relationship between spot prices and reservoir levels. Gjolberg and Johnsen (2001) investigate the relationship between both future spot prices and current reservoir volumes, and between future spot prices, and current spot prices, through regression analysis. The paper finds a significant influence of reservoir levels on 4 to 12 weeks of future prices. In von der Fehr et al. (2005) there is an analysis of a drought in the Nordics during 2002 and 2003. The drought is found to account for high price increases during the period through what the author deems tighter market conditions, i.e. total supply is needed to meet total demand with no or little residual. As the drought affected the reservoir levels of the generators, this supports the view that water availability is an important variable in an analysis of price determination of the Nordic electricity market.

Having introduced water as the most important variable, we now present papers that model the supply and demand functions of the market. Among the all literature that was reviewed in the course of this thesis, Hjalmarsson (2000) and Steen (2004) contain the most comprehensive supply and demand models, in terms of the variables employed. The papers combine findings from several relevant papers on the Nordic electricity market including Johnsen (1998), Forsund (1994) and Andersson (1997).

Hjalmarsson (2000) conducts an econometric study of market power in the Elspot market between 1996 and 1999. The paper uses temperature¹⁸, day length and industrial production¹⁹ as factors affecting the demand level. Temperature data on different cities in Sweden and Norway is aggregated by calculating a mean weighted average based on population. These 'national' temperatures for Sweden and Norway are then aggregated by weighting them according to the ratio of GNP between the countries, to create one temperature variable. The industrial production variable is calculated in a similar way. For representing the supply side, Hjalmarsson uses the inflow of water into reservoirs via rainfall, snowfall and snow melting. Water reservoir levels are mentioned as a second option. Based on his analysis Hjalmarsson (2000) is not able to reject the null hypothesis of perfect competition. The study does not find any evidence of market power.

Steen (2004) looks at bottlenecks, i.e. periods of capacity restrictions, in Southern Norway, the largest region of the Norwegian electricity market. Steen tries to identify market power by contrasting periods with and without bottlenecks. The paper uses a temperature variable to proxy for market demand and water reservoir levels are used as the supply variable. Steen refines Hjalmarsson's aggregation methods for temperature by weighting his temperature variable by the percentage of consumption rather than population. This takes into account the fact that more Northern cities will consume more electricity for heating purposes even though they have smaller populations than Southern cities. On the supply side Steen uses water reservoir levels based on the findings presented in Forsund (1994). Forsund proves that reservoir inflow is less exact in measurement than water reservoir levels. In periods of bottlenecks Steen detects price variations, which are suggestive of market power.

There is ample evidence in the literature that supports the use of water availability, measured either as inflows to reservoirs, reservoir levels, or precipitation in modeling a supply function for the Nordic electricity market. Temperature, day length and industrial production are

¹⁸ Li and Sailor (1995) and Sailor and Munoz (1998), find in a sample of US states that temperature is the most significant weather factor explaining electricity demand. Henley and Perison (1998) and Pardo et al. (2002), all obtain a significant explanatory power for air temperature in their modelling of electricity demand and price.

¹⁹ Beenstock et al. (1997) use industrial production as one main determinant of the electricity demand in Israel.

relevant in constructing a demand function. These findings are summed up in the table below. We now turn to papers on the English and Welsh electricity market to examine their efforts in modeling their integrated electricity market.

Table 1: Variables used in modelling the Nordic electricity market

Supply Side	Demand Side
Reservoir inflow Reservoir levels Precipitation	Temperature Day Length Industrial Production

3.2 Lesson from England and Wales

As no paper on the Nordics has yet tackled integration in a purely empirical study such as we aim to perform, we turn to papers on other markets with similar events, which may guide our methodology. In 2001, the allocation mechanisms of the electricity spot market were changed in England and Wales from the so-called “Pool” to the New Electricity Trading Agreement (NETA). We are interested in the methodology applied in representing the supply and demand side of the market, as well as how to analyse the change in the design of the market.²⁰

Green and Evans (2003) examine the effects of the change to NETA on electricity prices in England and Wales between 1996 and 2002. They perform a regression analysis on wholesale prices using a Hirschmann-Herfindahl-Index (HHI) concentration index of generation capacity ownership; and the ratio of available demand to registered capacity as independent variables. They also include a dummy variable which is 0 pre-NETA and 1 post-NETA to represents the change in market design. They find that increases in competition (HHI) and the level of spare capacity are significant explanatory variables. The first NETA dummy had no significance on prices. A second specification of their model employed a dummy variable for the 6 months pre-NETA. The second dummy was found to have a significant effect on prices by changing the behavior of tacitly colluding firms in the 6 months prior to market redesign.²¹

Bower (2002) also studies the development of wholesale prices on the electricity market in England and Wales from 1990 until 2002. In addition to NETA, Bower forwards regulatory interventions as the reason for change in prices. He runs a regression on price with a capacity concentration index²²; marginal generating cost²³; temperature and several dummy variables representing regulatory inventions, as independent variables. The key finding from Bower’s paper is that regulation related to limiting concentration was the most significant factors. The

²⁰ Although there is a plethora of literature on integration in the US market, the existence of price caps at the retail level, and the belief that vertical integration mitigates market power are concept foreign and antithetical to any discussion of market integration in the Nordics. See Mansur (2004).

²¹ Newberry (2003) contradicts the latter finding of pre-NETA collusion because of low concentration ratios in relevant industries, but not on methodological grounds.

²² This is calculated for thermal and nuclear plants by summing the squared capacity share of each generating firm for each plant type

²³ This is calculated as the ratio of fuel prices and thermal efficiency.

change in market design (NETA) was not found to be as significant as other factors for wholesale price determination.²⁴

The research papers presented above both employ variables representing the concentration and the marginal generation cost of electricity suppliers. We see those two variables as potential candidates, but reserve a detailed discussion, especially about concentration until section 4.3. The Papers on England and Wales provide us with examples of methodology that use dummy variables to assess the effects market design on price. The table below summarises the potential variables for representing supply and demand as well as market integration.

Table 2: Potential variables for our study

Supply Side	Demand Side	Market Integration
Water Availability Concentration Index Marginal Generating Cost	Temperature Day Length Industrial Production	Dummy Variable

4 On the Effects of Market Integration

We have examined literature on modelling the various effects on electricity prices. We now consider the theoretical foundations of electricity price determination. We begin by defining the competitive characteristic of the market, and our interpretation of market integration. We then present the relevant economic concepts and further literature on market integration and implications for prices. Our argumentation is twofold- firstly, we analyse the implications of market integration on market efficiency; secondly, we examine the relationship between market integration and market structure. We end with a working hypothesis for our empirical analysis.

4.1 Key Concepts

For our argumentation in the following sections we specify the competition type we consider most appropriate for describing the Nordic electricity market. We go on to examine the capacity constraints faced by electricity companies and their implications on price setting behaviour. Finally, our definition of market integration will be refined.

4.1.1 Cournot Oligopoly Competition and Capacity Constraints

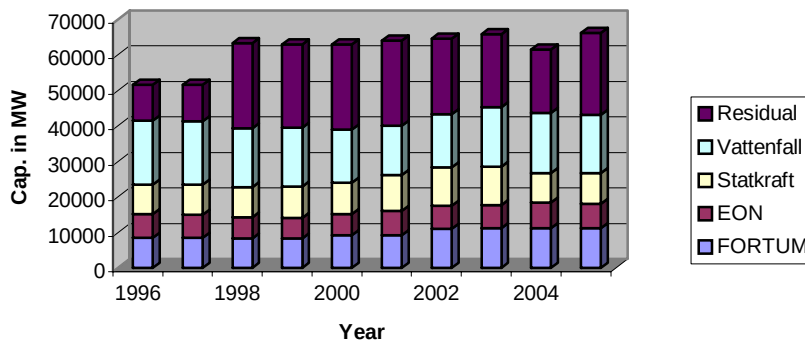
The Nordic electricity market, we find four large companies. This leads us to the assumption that the market is best described as an oligopoly. Abiding by relevant literature, a Cournot approach is used to model the market interaction, since companies compete on quantities.²⁵

²⁴ Fabra (2003) combines the Bower and the Evans and Green methodology, tackling the question of whether it was market structure or market design that was significant for wholesale prices. Her finding supports both ways, both market design and market structure were jointly responsible for the change in prices.

²⁵ This means firms theoretically choose output levels simultaneously first and then the market price is then set at such a level that demand equals total quantity produced. See Varian (1992).

An important feature of the Nordic electricity market is the capacity constraints face by generators, i.e. no generator could satisfy the whole demand of the market alone. The graph below displays the generation capacity held by the four big oligopolists. The ‘residual’ is the difference between their aggregated capacities and the total capacity in the market. Smaller companies own the residual. Rationally, assuming the generators have not added vast amounts of utilized capacity, graph 4 shows that none of the companies is able to satiate demand single-handedly.

Graph 4: Capacity constrained electricity generators

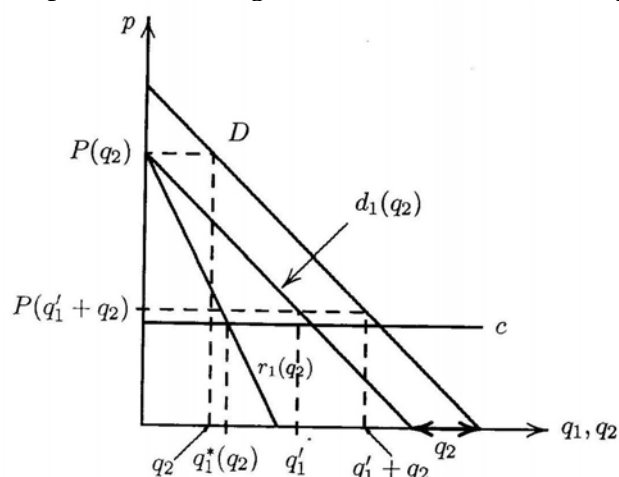


Source: Own Calculation

The belief that market functions in an oligopolistic manner with capacity constrained firms has implications for price setting behaviour. The following argumentation corresponds to the quantity-price diagram in Graph 5 shown below. Assume the case of two oligopolists competing for a market in Cournot fashion. Let company 2 be capacity constrained. Firm 1 assumes that firm 2 produces at quantity q_2 . Firm 1 then faces not the total demand curve indicated with D, but only the *residual demand* curve, which is labelled $d_1(q_2)$.²⁶ Regarding this curve, firm 1 does not have to fear any competition from firm 2, as it is capacity constrained. Therefore, theoretically, firm 1 will price in a monopolistic manner, which implies equating its marginal revenue with its marginal cost. In contrast to competitive pricing behaviour in the case of no capacity constraints ($q'_1 + q_2$), the quantity supplied to the market when taking into account capacity limitations is smaller ($q_2 + q^*_1(q_2)$) and the resulting price is higher. In effect, the fact that firm 2 is capacity constrained leads to a pricing behaviour that is far from being competitive. The crucial assumption is that of firm 1's expectation about output of firm 2 (q_2).

²⁶ The residual demand curve gives all possible combinations of prices and quantities for firm 1, given the output q_2 of firm 2.

Graph 5: Price setting behaviour in a Cournot setting with capacity constraints



Source: Cabral (2000), p.108

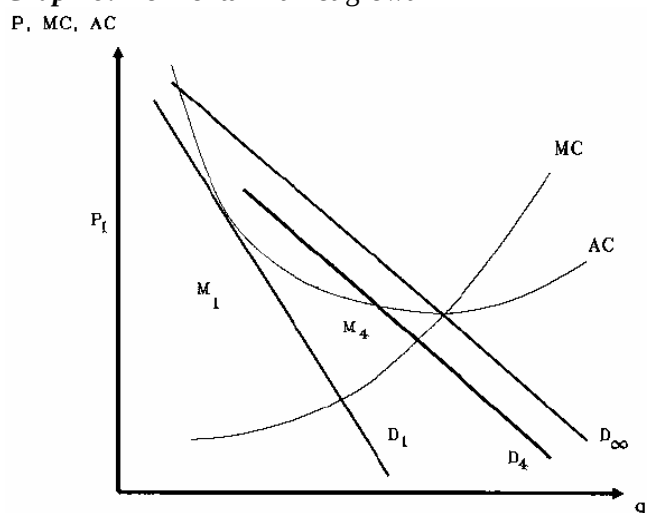
Following the argumentation presented above- every company involved in generating electricity should have the incentive to raise prices as they face a residual demand curve without competitive pressure.

4.1.2 Market Integration

As mentioned in the review of the Nordic market, traded volumes have increased over time. As no significant increase occurred in the turnover data when Finland joined Nord Pool, we chose to treat Finland's accession to Nord Pool as a continuous event within the general integration process occurring over time. This means integration takes into account the higher level of trade on the Elspot emanating from Sweden and Norway, as well as Finland.

It is also worth noting that we are observing horizontal market growth, which means more people demand a particular good.²⁷ In technical terms the slope of the demand curve declines, its intercept remains unchanged. The graph 6 below shows this as a rotation from D_1 to D_∞ .

Graph 6: Horizontal market growth



Source: Bresnahan and Reiss (1991), p .980

²⁷ See Neumann et al. (2001) for the distinction between horizontal and vertical market growth.

There is a theoretical objection to our market integration definition by Haaland and Wooton (1992), which states that market integration is not necessarily equal to a market enlargement since firstly, the enlarged consumer set in the integrated market may not share the same preferences as the initial consumer set, and secondly, there may be high trade costs. We address the objection by recognizing electricity as a homogenous good with a relatively inelastic demand and we account for potential differences in demand in our empirical analysis. Trade costs could be translated in the electricity market as transmission constraint costs. Since we analyse the system price we can safely ignore the transmission constraints- the objection is therefore moot.

As a corollary, we define the electricity market as truly “integrated” if the prices at each location in the market vary solely by the transmission cost between the locations. This is primarily based on the “law of one price,”²⁸ an economic law that states, in an efficient market all identical goods must have only one price. It is implicitly assumed transmission connections exist between locations.

4.2 Efficiency Gains via Market Integration

In this subsection we present the theoretical considerations that indicate the potential efficiency of market integration. The integration should reduce or eliminate the physical and economic factors that prevent prices across regional markets from converging to reflect the marginal cost of generation. Potential channels of efficiency include better use of generation and transmission resources, increased reliability of supply, and optimal investments in infrastructure. As a result of these market integration effects, prices should decrease on the wholesale market.

4.2.1 Price Signalling and Consumption Efficiencies

Considering the supply side of the market, an integrated wholesale market with an interface like Nord Pool is able to provide accurate price signals to potential investors in generation capacity. On the demand side, the wholesale market rations electricity to those consumers who value consumption more than the cost of generation, thereby increasing efficiency.²⁹ The closer market prices are to reflecting the marginal cost of generation through transparency provided by Nord Pool, the more likely the right level of consumption will occur. This will ensure allocative efficiency, and more importantly for us, will not distort investment incentives. Appropriate investment will limit price increases over the longer term in a competitive environment through ensuring efficient and sufficient generation capacity levels.³⁰

4.2.2 Reliability Efficiencies

Market integration, according Damsgaard and Green (2005), will also reduce reliability costs. In the non-integrated framework every company meets demand using its own capacity, while having to withhold an appropriate amount of spare capacity to ensure security of electricity supply. The new market allows for interconnectivity and sharing of capacity and reserves. With the assumption that the supply and demand shocks between plants are discrete; the joint

²⁸ See Burdett et al. (1983)

²⁹ See Trebilcock and Hrab (2005) and Trebilcock and Daniels (2000)

³⁰ See Vattenfall CSR Report 2006, http://www.vattenfall.com/cs-reports/filter.asp?filename=page_012.html

system would require a lower level of spare capacity and utilize more of the company's capacity to meet demand. There also would be a lower probability of failing to ensure security of electricity supply. In this way market integration leads to a more efficient usage of generation capacity.

Just as power generators must ensure reserved capacity, transmission system operators (TSO) need to ensure no transmission failures, minimize unplanned outages and maximize transmission capacities. Ancillary services and construction in support of these goals are procured by contract. A TSO's costs of upgrading the transmission and distribution network are recovered by passing on the costs to the wholesale consumers. This generates higher wholesale electricity prices. Integration allows for collective procurement of these services, and therefore reduces the costs of ensuring reliable supply of electricity on the wholesale market.³¹ As noted in von der Fehr et al. (2005), as the market develops, "further co-operation (integration) of system operations could potentially enhance efficiency."³²

4.2.3 Transaction and Generation Efficiencies

Potential cost reductions in the wholesale market can occur due to market integration through the reduction of transaction costs. For example, market integration may reduce the transaction costs of importing and exporting electricity. Electricity traders previously only engaged in trade so long as expected profits were greater than the transaction costs. The change to a universal market interface through the creation of Nord Pool, or the merging of law and regulation such as tariffs charges and transmission network access, have the effect of driving prices closer together, and lowering the average electricity price across the market.³³

There are also efficiency gains to be garnered from access to different energy sources, and combining them. One example of this phenomenon, put forward by Damsgaard and Green (2005), is when countries dependent on the generation of electricity from hydropower face a supply shock they can benefit from access to thermal energy from a country with more capacity in non-renewable energy sources. However, this is an efficiency only to be garnered in the short term, as repeated use of any generation source over the longer term will eventually drive up its price.

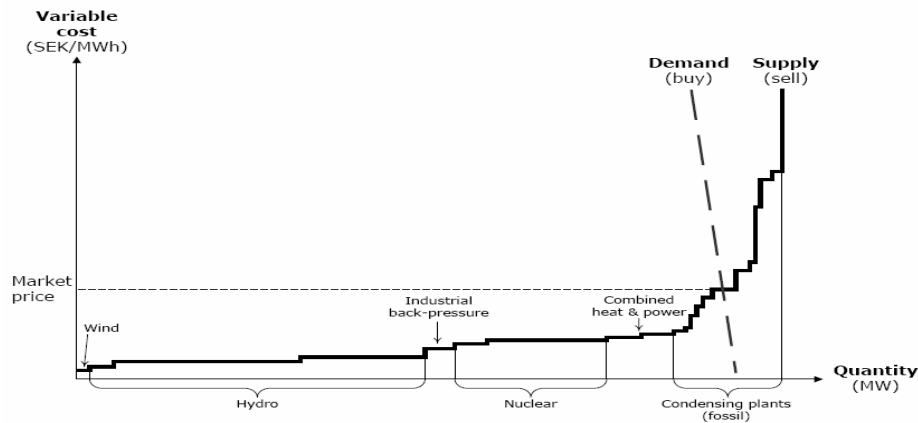
Combining thermal power and hydro capacities into a market will create the benefit of being able to produce electricity at lowest marginal cost given prevailing circumstances. The marginal cost of thermal power is directly proportional to the level of demand, in contrast the marginal cost of hydropower depend on the water levels in the reservoirs used to generate electricity. Therefore supplying electricity during peak hours through hydro sources is far more efficient than using thermal energy sources. Vice-versa, thermal power can be used during off-peak times more efficiently in comparison to using water, which may be scarce depending on weather conditions. Graph 7 below demonstrates marginal cost of different energy sources and the principle of price formation.

³¹ See LECG (2006)

³² von der Fehr et al. (2005) p. 26

³³ See Amundsen and Bergman 2000

Graph 7: The principle of price formation on the spot market



Source: The Energy Market Inspectorate (2006), p.3

Where countries are in different time zones (Helsinki is an hour ahead of Oslo and Stockholm), or have different daily patterns (for example meal times or working hours), the difference in peak and off-peak demand times will allow for efficiency gains from trade. Import of electricity during domestic peak hours and export of electricity during foreign peak hours will balance over the course of the day, but will allow for a reduction in the ratio of capacity to peak demand, resulting in efficient use of installed capacity. Random weather differences between countries and the differing levels of demand generated by weather conditions can be considered in a similar manner. Even if efficiencies of this nature are garnered previous to integration of the market, integration will allow for optimal adjustments in short spans of time and allow flexibility when necessary. The increased frequency of interaction between market participants will also augment efficiencies, which were prevalent previous to integration.

Strong empirical evidence also supports the economic theory that there are reductions in cost based on greater integration due to more efficient use of electricity sources. Hunt (2005) shows that the elimination of what he deemed “seams” in the Pennsylvania, New Jersey and Maryland (PJM) electricity market resulted in USD 29.9 MN in savings, in 2004. Furthermore, after adjusting for fuel costs, prices declined by 4.2% between 2003 and 2004.

We presented three ‘channels’ through which integration can create efficiency gains. All three theoretical considerations- price signaling and consumption efficiencies, reliability efficiencies and the transaction and generation efficiencies- should lead to lower prices on the wholesale market as traded volume increases.

4.3 Market Integration, Market Structure and Prices

Having analysed the potential efficiency gains through market integration, we now turn to market influences, which may qualify the extent of the integration effects. The literature presented below suggests that market structure may have an influence on the effects of integration, namely lower prices.

Amundsen et al. (1998) evaluate the effect of deregulation and free trade on electricity prices in Norway, Sweden and Finland. In a multi-country Cournot model they focus on the effect of increased competition on market power and the degree of monopolistic pricing prevalent on the market. While they find much higher prices in the Cournot model than in the competitive

equilibrium in autarky, allowing for inter-country trade makes the prices in Cournot equilibrium approach a competitive level. Hence the conclusion- market integration has the potential to reduce prices.

However, Amundsen and Bergman (2000) use the same multi-country model and qualify this effect of integration. They find that an increasing degree of cross-ownership among generators and power-producing firms in the Norwegian-Swedish electricity market, i.e. a lower number of independent companies, may re-establish market power that initially was reduced via integration. In their model, partial ownership relations among players tend to increase horizontal market power and therefore the price of electricity. This indicates that the effect of integration on price needs to be qualified by the countervailing effect of concentration, due to the potential exercise of market power.

In following subsection, we first identify the effect of market integration on market structure i.e. the concentration or the number of firms that the new market size can sustain, and in a second step we recognize the ultimate effect on price. In our review we consider the international trade literature on regional integration and the literature on industrial structure in which this topic has been treated.

4.3.1 The Effect of Market Integration on Market Structure

The most relevant effects of market integration are the dynamic effects³⁴, the so-called *pro-competitive gains* from trade between countries. As the market grows, the four national producers cannot indulge in reciprocal dumping and price discrimination between markets anymore.³⁵ Most oligopoly theories, assuming free entry, predict that continued market integration, should encourage new entrants to join the market as growing demand offers profit opportunities.³⁶ We would therefore expect the number of firms on the market to increase, and the concentration to decline.

In 1998 there were players active in the Finnish market, which already had existing capacity, at least in the form of spare or reserve capacity every producer maintains for a sudden spike in demand. This allowed them free entry to the integrated Elspot market. For new players, this assumption of free entry is unrealistic. Given the high capacity investments necessary to set up a hydro or thermal plant, the fixed costs associated with entry into the electricity market lead us to expect that there will be a reduced number of new entrants compared to market growth in an industry with free entry. Neumann et al. (2001) suggests “fixed costs, particularly if sunk, may pose as a major barrier to entry and exit.”

In theory, there may be three effects that work against this diminishing concentration we expect due to market integration. The *firm exit effect* implies that a less concentrated market structure will lead to a more competitive environment and this in turn will lead to lower profits.³⁷ As a result, some companies may earn negative profits and will leave the market, leading back to an increase in concentration.

³⁴ In contrast to the dynamic effects like an increase in competition, static effects of market integration describe the trade creation and trade diversion. See Sapir (1992), p.1498ff.

³⁵ Reciprocal dumping described the behaviour of strong national players who are able to use their market power on separated markets and to price discriminate between the markets. See Krugman and Brander (1983)

³⁶ See Bresnahan and Reiss (1991)

³⁷ See Markusen et al. (1995)

The *firm size effect* describes that fact that firms incur higher fixed costs in growing markets. Therefore a market size increase necessitates firm growth, most easily achieved by a merger or acquisition.³⁸ Consequently, the relative number of players on a market decreases and concentration increases.³⁹ This line of argument is strengthened by the fact that we have seen several big acquisitions in recent years on the Nordic electricity markets, a sign of external firm growth.⁴⁰

A particularly interesting case is put forward by Sutton (1991) and Lyons et al. (2001) who emphasize the *effect of endogenous fixed costs*. This effect describes that the choice of the level of a fixed cost, like R&D or advertising expenses, is set at a firm's own discretion and thereby endogenous to the competitive process. As market size increases, the incentive to use large pre-emptive investments increases and may lead to an escalation of overhead fixed expenditures. Large advertising expenses in the soft drink industry for example will put enormous pressure on smaller competitors to invest heavily; some may have to exit the market.⁴¹ As a result, the negative relationship between concentration and market size may break down, as the "growth-entry mechanism"⁴² does not work in all industries.

We think that this argument does not hold for our case. The electricity industry parallel of high fixed cost would be investments in generation capacity. The big players on the Nordic electricity market do not have free capacities to threaten smaller competitors. All players are capacity constrained as shown in graph 4. There is no binding need for smaller players to grow when the market grows. They can still offer their bid on the transparent Elspot market and no other company can quickly or inexpensively take their share.⁴³

In conclusion, we expect a pro-competitive effect in the direction of less concentration but at the same time firm exit, and firm size effects work in the opposite direction but with less impact. Even if no real change in market structure took place, there may be an effect on price just on basis of *the perceived type of competition* on the market. Markusen et al. (1995) describes a so-called *pure pro-competitive gain* from trade in a Cournot set-up. On a larger market individual oligopolists *perceive* a more elastic demand curve, even if no additional trade occurs on the integrated market. The underlying effect at work is the *threat* of entry because the increased market size offers profit opportunities for potential new entrants. Moreover, consumers can theoretically choose more freely from different suppliers. This leads to a reduction in mark-ups and an increase in industry output.⁴⁴ Following microeconomic theory this will, ceteris paribus, lead to lower prices on the market.

Summing up the findings in the literature, we think that there is a potential for a decrease in concentration over time on the Nordic electricity markets via pro-competitive effects. However, due to the firm size and exit effect and the high entry barrier of fixed costs, we do not expect a high decrease in concentration in the Nordic market. This is categorically supported by Schmalensee (1989) who states "concentration levels do not decline much with increases in the size of the economy."⁴⁵

³⁸ See Neumann et al. (2001)

³⁹ See Pryor (1972)

⁴⁰ See Codognet et al. (2002)

⁴¹ See Cabral (2000)

⁴² Neumann et al. (2001), p.2

⁴³ Since electricity as a homogenous good, we do not expect high consumer sensitivity to such endogenous investments.

⁴⁴ See Neumann et al. (2001)

⁴⁵ Schmalensee (1989), p.992

4.3.2 The Effect of Concentration on Prices

A relevant question that follows from the previous considerations is whether the change in concentration will in turn lead to lower prices. Schmalensee (1989) notes that seller concentration is positively related to the level of price when comparing cross-sectional data involving markets in the same industry. The higher the degree of concentration, the greater the potential for market power and hence the stronger the ability to raise prices. Cabral (2000) also demonstrate this relationship exist vice-versa.⁴⁶ A lower degree of concentration implies prices that are closer to a competitive level. Further support of a negative relationship between concentration and prices comes from, Andersson and Bergman (1995), Amundsen et al. (1998), Amundsen and Bergman (2000), and Johnsen et al. (1999) all find that a lower market concentration leads to increases in competitive behavior in the form of lower prices.

The negative relationship between concentration and price has to be put into perspective, through the introduction of market power. A firm with market power will have the ability to raise prices above the competitive level. The degree of market power depends on different factors.⁴⁷ One factor is the *market concentration* as discussed in the previous subsection and *entry is deterred*⁴⁸ by large sunk costs that cannot be recovered upon exit.⁴⁹ As a second factor, the *demand elasticity* in electricity markets is relatively inelastic. An increase in price leads only to a small reduction in quantity demanded. As a third factor, *collusive behaviour* is more probable and easier to sustain if there are less firms.

Although there may be some theoretical considerations that suggest market power on the Nordic electricity market, empirical analyses conducted so far have found only limited indications of the potential and use market power. Hjarlmarsson (2000) could not reject the hypothesis of no market power, while Steen (2004) found only limited use of potential market power. Amundsen and Bergman (2005) use a PoMo⁵⁰ simulation model for detecting market power of hydropower generators during the period of high prices in 2002/2003. The paper finds the high prices were caused by scarcity of hydro resources and a low elasticity of demand- not by market power. The paper argues that this good performance of the Nordic electricity market is based on simple but sound market design, and a successful dilution of market power. However, Wolfram (1999), finds that even with the existence of market power, British generators did not exercise it due to the threat of government intervention and burdensome regulation. This may also be case in the Nordics. Market power may exist, but regarding the exercise of market power “convincing proofs are lacking”⁵¹.

In conclusion, as a result of a horizontal market growth, the concentration in the integrated market should decrease by a small margin. The change in concentration should lead to a decrease in prices as market power, or least the exercise of market power on the Nordic electricity market has been limited.

⁴⁶ It does not take a large number of firms to achieve a Cournot result similar to that of perfect competition. As the number of firms increases, the total output increases which drive prices down. Cabral (2000)

⁴⁷ See Cabral (2000), p.160

⁴⁸ See Bain (1956) for a seminal work on barriers to entry.

⁴⁹ See Schmalensee (1989), p.969

⁵⁰ The PoMo model is designed to take the special factors of hydropower into consideration in estimating future market prices. It assumes the Nordic market is competitive, and has risk neutral producers that know the amount of water in the reservoirs; output from alternative generation sources; probability of inflows and demand. The weekly prices the PoMo model predicts are similar to the Nord Pool average weekly spot prices. See Amundsen and Bergman (2006), p.154.

⁵¹ Amundsen and Bergman (2006), p.157

4.4 Our Hypothesis

Based on the reasoning in the two preceding sections, we found two effects through which market integration will potentially impact prices. Section 4.2 showed that market integration leads to efficiency gains that should result in lower prices on the wholesale market. In addition, based on theory and empirical evidence presented in Section 4.3 we expect market integration to lead to a decrease in concentration which should in turn result in a decrease in prices on the market.

Therefore our hypothesis is:

Market integration will have a negative effect on the Elspot system price. An increase in market integration will drive down wholesale prices.

5 Empirical Analysis

5.1 Empirical Strategy and Variables

The tool we will use to test our hypothesis is regression analysis, through which we will isolate the effect of market integration on prices. In this analysis we try to represent all main determinants of wholesale prices in the Nordic market. These include the main factors influencing the aggregate supply and demand side of the market and a variable representing the market integration. We look at data from January 1996 to December 2004 on a weekly basis, which gives us a total of 466 observations⁵². We focus solely on Norway, Sweden and Finland.⁵³

Our *dependent variable* (System) is the Elspot system price. As described in the Nordic market review section- this is a theoretical price, which disregards transmission constraints. We use the system price in our model since it allows us to more clearly isolate factors influencing the market price. Analysing the area prices paid by final wholesale buyers would introduce too much ‘noise’ in our analysis due to stochastic factors; for example transmission constraints.⁵⁴

The system price is measured in Norwegian Kroner per megawatt-hour and is obtainable directly from Nord Pool AS. Since the system price was nominal, and all other variables are measured in real terms, we converted this nominal variable into a real variable by using the Norwegian Consumer Price Index (CPI). The Norwegian CPI was obtained from the International Monetary Fund’s, International Financial Statistics (IFS).

When choosing the *independent variables* we focus at first on variables representing the degree of market integration because this relates directly to our research question. Secondly, in order to isolate the effect of integration, we focus on factors influencing the aggregate supply and demand of the market thereby accounting for their effect on system price.

⁵² The initial number of observations is 468. In the cause of the robustness tests two influential observations will be removed.

⁵³ The omission of Denmark from our analysis will be discussed in the limitations section.

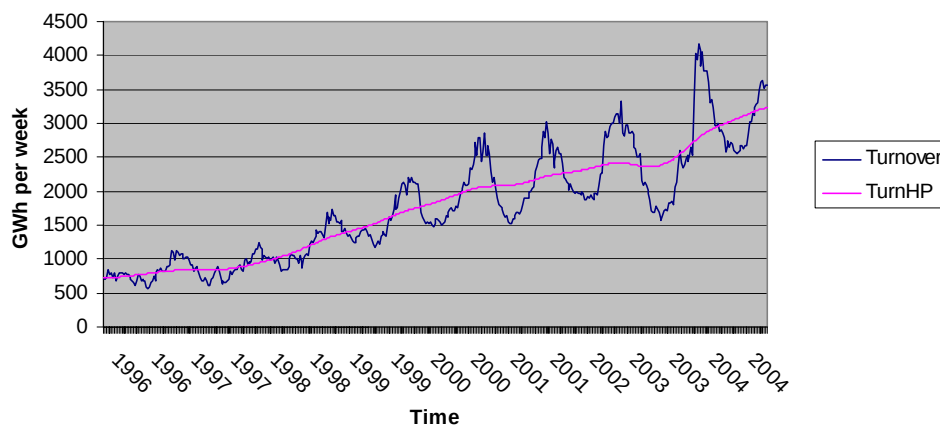
⁵⁴ For example, random events such as a bad snowstorm would not allow us to isolate the effect of non-stochastic factors’ influence on price changes.

The first independent variable we examine is total volume traded on the Nord Pool spot market. We use turnover (*TurnHP*) to represent the degree of market integration in the Nordics. This is in line with our definition of market integration in 4.1.2 as a continuous event occurring over time. As we do not understand market integration as a single event, we do not follow Green and Evans (2003) and Bower (2002) in using a dummy variable approach. Employing a dummy would rather represent a one-time change in prices and not a continuous effect of market integration.

The turnover variable should not only represent the increased volumes that are demanded by customers on the wholesale market, but also the quantities that are bought by big generating companies and then resold to their customers. This will capture the generation efficiencies described above.⁵⁵ Based on the findings of section 4.2, we expect that as volumes traded on the Elspot increase, the system price should decrease due to efficiency gains. The expected sign of *TurnHP* is negative.

The volume traded was obtained from Nord Pool's FTP server and is measured in gigawatt-hours per week. We used a Hodrick-Prescott-Filter⁵⁶ for isolating the linear trend in our turnover variable. The reasons for using the HP-Filter are twofold: First, we are interested in the growth trend of the traded volume, not in its seasonal variation.⁵⁷ Second, we prevent simultaneous causality between the turnover variable and the dependent variable. Simultaneous causality could arise as not only the turnover, i.e. the intersection of supply and demand, determines prices, but also at the same time prices determine which level of turnover occurs. As a result, turnover would be correlated with the error term. The OLS estimator would be biased and inconsistent. By just focusing on the long run trend of the turnover, weekly turnover observations will not be able to explain the weekly prices anymore.⁵⁸ In the graph below we show the original series (Turnover) and the final variable (*TurnHP*).

Graph 8: Comparison of Turnover and TurnHP



Source: Nord Pool, authors' calculation

⁵⁵ We see that with this variable an increase in turnover does not necessarily imply an increase in demand, but we accept this weakness in return for having the turnover variable representing the efficiency gains.

⁵⁶ The HP-Filter is a usual method to "smooth-out" the estimate of the long-term trend component of a series. We chose the HP-Filter over a simple linear trend because the HP-Filter still covers some long-term cyclical pattern, e.g. caused by business cycles, which a simple linear trend would not cover.

⁵⁷ The demand variables temperature, length of days and industrial production all show a lot of seasonal patterns, so the seasonal movement in the systemprice will still be explained.

⁵⁸ For the basic concept of simultaneous causality, see Stock and Watson (2003), p. 251

When choosing other *independent variables* we do not simply use volumes demanded and supplied because this would lead to a simultaneous causality bias, i.e. the explanatory variables demand and supply could explain the price level, but at the same time our dependent variable will determine how much is supplied and demanded.⁵⁹ Therefore we decided to use variables that instrument for demand and supply shifts.

In developing our model, we first focus on the variables that shift the marginal cost function of the power industry. Our first explanatory variable on the supply side is water reservoir levels as the majority of electricity in the Nordics, about two-thirds, is generated from hydroelectricity. In addition, the literature on the Nordic markets mentioned above stresses the importance of reservoir levels in any analysis of the electricity market. We follow Steen's (2004) methodology of using water reservoir levels, based on his convincing argument that inflow is less exact than water levels.⁶⁰ This is also supported by Forsund (1994).⁶¹

The marginal cost in hydropower generation is close to zero. However, producing an extra amount of power today means giving up the opportunity to store that amount of water and supply it to the market at a later stage. The opportunity cost can therefore be large, and certainly highly variable, depending on circumstances, such as the season and precipitation, and expectations.⁶² Therefore, water levels in the reservoirs determine the marginal cost of electricity generation and establish the "value of water". In general, when water reservoir levels increase, the value of water and therefore the opportunity cost and marginal cost of water decrease. This leads, in technical terms, to a left shift of the supply curve, leading to lower prices. The opposite logic applies to decreasing water levels. We expected a negative relation of the *Water* variable with our dependent variable.

The weekly data points for water reservoir levels are sourced in percentage value from the Organisation for the Nordic Transmission System Operators (Nordel). We have aggregated the national data weighted by each country's share of total water reservoir capacities to create a weekly average of water reservoir levels.

Besides hydropower, graph 7 in section 4.2 shows that thermal power is relevant for determining the price level for electricity because it is the most adjustable energy source and is sold 'on the margin'. The marginal cost of thermal power production increases with the level of demand. As a proxy measure of the contribution of thermal energy to price determination we use Finnish coal prices. Coal is the most important thermal power source in Finland, the largest producer of thermal energy in our study.⁶³ We can expect a positive relationship between the price of coal and the system price because a rise in coal prices means a rise in thermal generation prices. This will lead to a higher marginal cost and so it will shift the supply relationship upwards, leading to higher prices. We obtained the coal price index

⁵⁹ As mentioned before, this simultaneous causality makes the explanatory variable correlated with the error term, which in turn makes the OLS estimators biased and inconsistent.

⁶⁰ Hjalmarsson (2001) uses measurements, like the inflow to the reservoirs through rainfall or snowfall. This would be a completely exogenous input, but would also give us only a less precise estimate of water levels.

⁶¹ We note that the reservoir levels may be partly endogenous as producers may adjust the water level for strategic reasons. See Steen (2004)

⁶² See Amundsen and Bergman (2006)

⁶³ A graph showing the evolution of electricity generation in Finland from 1971-2004 is to be found in the Appendix A.1 and clearly indicates that coal is the primary thermal source in Finland.

data from the International Energy Agency (IEA) as a quarterly index of the wholesale price level between 1998 and 2004. The variable is named *Coal*.⁶⁴

Another relevant factor on the supply side is the market concentration. In perfect competition, a small increase in concentration will not have a big effect on prices. In the Nordic electricity markets the high concentration on national markets was one major reason for market liberalization, and integration was expected to drive down prices.⁶⁵ As the four big companies still hold a significant amount of generation capacity in the integrated market, we consider concentration a relevant variable. Based on findings in section 4.3.2, an increase in concentration should lead to an increase in prices, and therefore holds a positive relationship with our dependent variable. Although previous studies have indicated little exercise of market power on the Nordic market, those are limited in number, and concentration was consistently used in the research on the England and Wales electricity market.

We calculate a concentration ratio (*Con*) using the market shares of the four largest electricity generators in the Nordics. We base the market shares on the installed capacity of the four generators in the adjustable generation field,⁶⁶ i.e. hydro and thermal power, since the adjustable aspect of these energy sources allows for strategic behaviour, like reacting to market conditions, in the short run.⁶⁷ From annual reports we created a yearly concentration ratio based on the sum of shares of adjustable capacity for the four biggest players, from 1996 to 2005.

For the *demand side*⁶⁸ the most frequently identified variables in the literature are temperature, the length of days and industrial production.

We start by using a temperature variable (*Temp*) to gauge demand. As temperature decreases consumers require larger electricity supplies to heat their homes or businesses.⁶⁹ We expect a negative relationship of temperature with our dependent variable. We obtained temperature for the largest population centres in Finland, Sweden and Norway from the Swedish Hydrological and Metrological Institute (SHMI), the Finish Meteorological Institute (FMI) and the Norwegian Meteorological Institute. We created a weighted average for every country based on the share of the population and distance from the equator.⁷⁰ The final temperature averages were again re-averaged into a weighted average for the Nordics by population.

We also collected length of day data (*Daylength*). We expect there to be a negative correlation with the system price, as less minutes of sunlight cause higher prices of electricity, driven by increased demand for lighting by homes and businesses. We obtained length of the day from

⁶⁴ Since these indexes are only available on a quarterly basis, we assumed a constant index level for the entire month. A simple method like this does not yield perfect results, but the variation within months should be small and the benefit of having data on a weekly basis clearly outweighs the lack of accuracy.

⁶⁵ See Danish competition authority (2003)

⁶⁶ See Finish competition authority (2006)

⁶⁷ Nuclear energy for example can not be turned on or off in the short run and instead will provide a continuous base load.

⁶⁸ We loosely abide by the Hjalmarsson (2001) (and Johnsen (1998)) demand side methodology for our empirical strategy with one exception. Steen refines Hjalmarsson's aggregation methods for temperature by weighing the final temperature variable by percentage of consumption rather than population. This takes into account the fact that more Northern cities will consume more electricity for heating purposes even though they have smaller populations than Southern cities.

⁶⁹ Compare Damsgaard and Green (2005).

⁷⁰ The more northern cities were given greater weight since their 'heating period' throughout the year is longer. In addition, based on temperature differences, these regions require more electricity for heating purposes compared to a region more south.

sunrise to sunset in minutes of daylight for Stockholm and Umeå from Geoscience Australia⁷¹. The results were averaged.

Finally, we introduce industrial production (*IP*) as a variable in order to represent the industrial demand for electricity in major industry and manufacturing. The higher demand for electricity from higher industrial activity will result in higher prices on the Elspot market providing supply does not increase as well. We expect the relationship of industrial production to the system price to be positive. The industrial production statistics were collected from the International Monetary Fund's, IFS publication. The industrial production is measured as a weighted average of the Finish, Norwegian, and Swedish industrial production indexes. These indexes are non-seasonally adjusted and rebased to our starting year 1996.⁷² To sum up this section we present a table with the independent variables that will be used in our regression analysis.

Table 3: Employed variables and their expected sign

Independent Variables	Variable Name	Expected Sign
Turnover	<i>TurnHP</i>	-
Water Reservoir Levels	<i>Water</i>	-
Concentration ratio	<i>Con</i>	+
Coal Price	<i>Coal</i>	+
Temperature	<i>Temp</i>	-
Length of day	<i>Daylength</i>	-
Industrial Production	<i>IP</i>	+

5.2 Regression Analysis

In this section our regression analysis will be presented.⁷³ We begin with an initial regression model including all our explanatory variables. We then enter into an iterative procedure whereby we exclude insignificant and problematic variables to arrive at a final regression model. This model only contains independent variables with coefficients that are statistically significant at the 10% level. We refine the model with a dummy variable to isolate the effect of integration on price determination more distinctly.

5.2.1 Initial Regression Model and Preliminaries

We used SPSS to set up our initial regression model with all variables presented in section 5.1. The method for estimating the coefficients is ordinary least squares (OLS). In order to reduce the initial regression model into a final model that includes solely highly significant explanatory variables, we apply a backward linear least squares multiple regression procedure

⁷¹ See <http://www.ga.gov.au/geodesy/astro/>

⁷² Since these indexes are only available on a monthly basis, and the rest of the data is on a weekly basis, a simple interpolation was used to derive weekly estimates of industrial activity. We assumed a constant industrial production level for the entire month. A simple method like this does not yield perfect results, but the variation in activity within months should be small and the benefit of having data on a weekly basis clearly outweighs the lack of accuracy.

⁷³ In a first step, we performed an initial data analysis by looking at simple correlations to get a rough indication of which variables have explanatory power. See Appendix A.3 for the simple correlations table.

as used by Bower (2002)⁷⁴. This leads us to a model that contains just variables that are significant at the 10% level. The SPSS coefficients table for the initial regression analysis is shown below.

Table 4: Coefficients of the initial regression model

Coefficients ^a					
Model		Unstandardized Coefficients		Standardized Coefficients	Sig.
		B	Std. Error	Beta	
1	(Constant)	-142,749	97,069		,142
	TurnHP	,052	,012	,456	,000
	Con	7,790	1,802	,307	,000
	Water	-,660	,138	-,176	,000
	Temp	-16,132	2,252	-,325	,000
	Daylength	-,034	,024	-,067	,163
	IP	-,378	,343	-,056	,271
	Coal	-,351	,146	-,277	,017

a. Dependent Variable: System

We reserve commenting on features like R^2 or coefficients until we arrive at our final model. At this stage, it is only relevant that the variables *TurnHP*, *Con*, *Water* and *Temp* are statistically significant at the one percent level, *Coal* is significant at the 5% level. The intercept as well as *Daylength* and *IP* are not significant at the 10% level.

As a next step, we examined the coefficient correlations, to check for multicollinearity. The table below shows that *Coal* and *Con* as well as *Coal* and *TurnHP* strongly move together which indicates multicollinearity between those explanatory variables. Correlations figures as high as 0.853 and -0.885 indicate strong multicollinearity. In order to cure this problem the first differences of *Coal* were computed. However, the new variable was not significant in the regression and therefore *Coal* was excluded from our analysis.⁷⁵

Table 5: Coefficient Correlations

Model		Coal	Daylength	Water	Con	Temp	IP	TurnHP
1	Correlations Coal	1,000	-,132	-,073	,853	,114	-,075	-,885
	Daylength	-,132	1,000	,147	-,021	-,661	,463	-,039
	Water	-,073	,147	1,000	,126	-,208	,179	-,055
	Con	,853	-,021	,126	1,000	,002	,075	-,819
	Temp	,114	-,661	-,208	,002	1,000	-,318	,025
	IP	-,075	,463	,179	,075	-,318	1,000	-,261
	TurnHP	-,885	-,039	-,055	-,819	,025	-,261	1,000

Based on the finding from table 4, in a first iteration the variable *IP* was excluded from our analysis because it showed the lowest significance.⁷⁶

When re-running the regression without *IP*, the variable *Daylength* still was not found to be significant.⁷⁷ Therefore, also *Daylength* was dropped from the analysis.

⁷⁴ The initial regression run contains all the significant candidate explanatory variables from the previous step. The independent variable with the highest p-value, meaning the statistically least significant, is then eliminated and the regression repeated. This sequential elimination of insignificant independent variables is repeated until the p-values of all the remaining variables are equal to or less than 0.10. See Bower (2002), p.26

⁷⁵ Another reason for excluding coal was that it does not have the expected sign in our regression.

⁷⁶ In addition, the simple correlation between *IP* and *System* was not significant.

⁷⁷ From a graphical analysis we see that the time series of *Daylength* includes a lot of cyclical variation. This kind of variation is also covered by *Temp* which also represents the demand side of the market.

Through these preliminary steps the variables *Coal*, *IP* and *Daylength* were excluded from the analysis due to multicollinearity problems and missing explanatory power in an initial regression analysis. In the following step, only the remaining explanatory variables *TurnHP*, *Con*, *Water* and *Temp* were used.

5.2.2 Model 1: Regression Results and Testing for Parameter Stability

Having established the variables of importance we now set up the reduced regression model. The SPSS output for model 1 is shown below.

Table 6: Coefficients table for Model 1

Coefficients ^a					
Model		Unstandardized Coefficients		Standardized Coefficients	
		B	Std. Error	Beta	
1	(Constant)	-387,934	45,740		
	TurnHP	,022	,004	,192	
	Con	11,871	,911	,467	
	Water	-,641	,137	-,171	
	Temp	-18,072	1,699	-,364	
					t
					Sig.

a. Dependent Variable: System

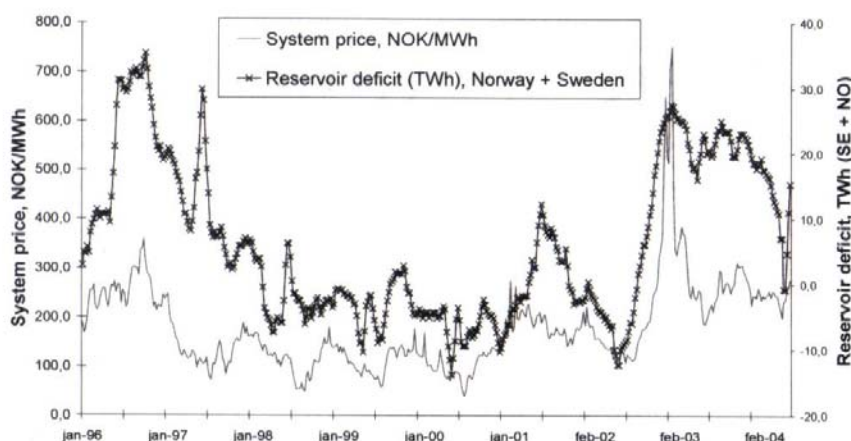
In Model 1 all explanatory variables are significant. All the variables except *TurnHP* yield the expected sign. This implies that an increase in volume traded on Nord Pool leads to an increase in prices, rather than the decrease, which we expected.

In order to examine the turnover variable more closely, we performed a test for parameter stability over time. We split our observation period into two halves. The first half extends from the beginning of 1996 until the middle of 2000 and the second half from the middle of 2000 until the end of 2004.⁷⁸ The test shows that the coefficient for turnover is not stable over time. Moreover, the computations indicated that the turnover variable has a negative impact on the system price in the first half of the total observation period, and a positive impact in the second half.

In trying to understand why a higher turnover during the second half of our observation period led to even higher prices, we feel it important to note that the Nordic power markets are dominated by hydropower. This is crucial since the second half of the observation period roughly corresponds to a period of drought in the Nordic countries. Based on the water reservoir deficits shown in the graph below, we identify a *drought period* in the middle of 2001 and from end 2002 till end 2004. All other times will be referred to as *non-drought period*. The graph below shows water reservoir deficits during the years 1996-2004.

⁷⁸ The first period is represented by our model 1, for the second period a dummy variable is added, which takes the value 1 exactly from the middle of 2000 until the end of 2004. Moreover, interaction terms of this dummy with all variables are computed. The relevant SPSS output can be found in the Appendix A.4.

Graph 9: Water reservoir deficits from 1996-2004



Source: Damsgaard and Green (2005), p.62⁷⁹

Due to the drought and the associated deficits in the water reservoirs levels, generators of hydropower could not produce as much electricity as before. Therefore, significantly less hydroelectricity was offered at the Elspot.⁸⁰ Taking into account that the Nordic market is dominated by hydropower, and assuming no change in demand, this supply shock should have led to a sharp increase in prices on the market, *ceteris paribus*.

The effect on price induced by the severe supply shock can be assumed to be stronger than the long-run efficiency gains of market integration.⁸¹ Hence the effects of the supply shock caused by the drought period are a reasonable explanation for the positive relationship between turnover and system price. The underlying reasons will be explored further in the interpretation sections 6.1.2 and 6.1.4.

In order to examine this claim, a dummy variable *Drought* was created that takes the value 1 for the period of drought, and the value 0 for non-drought periods. As we are especially interested in the turnover variable, we seek to gauge the exact effect that turnover had on prices during the drought and non-drought. In technical terms, we examine in what magnitude the coefficient of the variable *TurnHP* differs between the two periods. Therefore, we compute an interaction term⁸² with *Drought*⁸³, which will represent the additional effect the turnover variable has during the drought period.

$$Interact_DrTurnHP = Drought * TurnHP$$

From theory we expect that the impact of turnover, i.e. of market integration, on price should be negative. However, the severe supply shock during the drought period and its price increasing effect is assumed to dominate the market efficiencies that arise from market

⁷⁹ The graph was translated from Swedish to English.

⁸⁰ See von der Fehr et al. (2005) who find tighter market conditions, i.e. less excess capacity, during the years 2002 and 2003.

⁸¹ Von der Fehr et al. forwards that the effect of market integration had not been sufficient counter the supply shock on the scale witnessed during the drought. Further integration, he postulates, could be a possible solution to relieve the tightness of the market during a shock.

⁸² In contrast to using an interaction term, a simple dummy variable approach would just account for a general change in intercept for the regression line.

⁸³ We also computed an interaction term for Water, but as shown in Appendix A.5 this variable was not significant.

integration. Therefore we expect the interaction effect to have a positive coefficient in our regression analysis.

5.2.3 Model 2: Final Regression Results

In Model 2 we employ all explanatory variables used in Model 1, and add *Interact_DrTurnHP* in order to isolate the period-specific effects of the turnover variable during the drought. The *Interact_DrTurnHP* shows in how far the turnover variable has a different impact during the drought period compared to the non-drought period. We estimate the regression equation:

$$System_t = \beta_1 + \beta_2 \cdot TurnHP_t + \beta_3 \cdot Con_t + \beta_4 \cdot Water_t + \beta_5 \cdot Temp_t + \beta_6 \cdot Interact_DrTurnHP_t + u_t$$

The SPSS output is shown below.

Table 7: Regression Output for Model 2

Model Summary^a

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,739 ^a	,547	,542	52,68682

a. Predictors: (Constant), Interact_DrTurnHP, Temp, Water, Con, TurnHP

b. Dependent Variable: System

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1540092	5	308018,417	110,962	,000 ^a
	Residual	1276915	460	2775,901		
	Total	2817007	465			

a. Predictors: (Constant), Interact_DrTurnHP, Temp, Water, Con, TurnHP

b. Dependent Variable: System

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-200,462	33,606		-5,965	,000
	TurnHP	-,026	,005	-,244	-4,951	,000
	Con	9,001	,761	,383	11,831	,000
	Water	-,595	,107	-,172	-5,575	,000
	Temp	-14,206	2,227	-,291	-6,263	,000
	Interact_DrTurnHP	,035	,003	,551	12,106	,000

a. Dependent Variable: System

Model 2, our final model, yields an R^2 of 0,547, which means that 55% of the variation in the system price can be explained by the explanatory variables we used. Taking into account the relatively small number of variables we ended up with, we evaluate this as a decent level of R^2 . The significance of the F-test shows that the explanatory power of the model is different from zero in a statistical sense.

All explanatory variables are significant at the 1% level and show the expected sign. According to the absolute values of the standardized coefficients, the *Interact_DrTurnHP* variable is the most important in explaining system price.

As mentioned above, *Interact_DrTurnHP* only has an impact during the drought period as the *Drought* dummy is set equal to 0 at all other times. As there is no effect on the non-drought period, we omit the interaction term from an estimated model of the non-drought period.

Estimated model for the non-drought period:

$$System_t = -200.462 - 0.026 \cdot TurnHP_t + 9.001 \cdot Con_t - 0.595 \cdot Water_t - 14.206 \cdot Temp_t$$

For the drought period the interaction term has to be taken into account. The coefficient of *Interact_DrTurnHP* has to be added to the coefficient of *TurnHP* to get the total effect of the turnover on system price, so $-0.026 + 0.035 = 0.009$.⁸⁴

Estimated model for the Drought period:

$$System_t = -200.462 + 0.009 \cdot TurnHP_t + 9.001 \cdot Con_t - 0.595 \cdot Water_t - 14.206 \cdot Temp_t$$

The *TurnHP* coefficient is most relevant to the analysis. Our result implies that an increase in turnover during the non-drought period by one GWh per week, holding all other variables constant, will decrease the system price in NOK per MWh on average by 0,026. During the drought period, an increase in turnover by one GWh per week will on average increase the system price in NOK per MWh by 0,009, holding all other variables constant.⁸⁵

Beginning with an initial regression model with all the variables mentioned in section 5.1, we used an iterative procedure to arrive at a reduced model. This model contained solely variables that were significant at the 1% level. The striking result we obtained for *TurnHP* required the use of an interaction term to distinguish the effect of turnover between the two periods defined above. In conclusion, the turnover variable has a negative impact on prices in the non-drought period, and a positive impact in the drought period.

5.3 Robustness

In this section we present the results from several robustness tests in order to check the internal validity of our model.⁸⁶

We excluded two outliers⁸⁷ because we are striving for general results and the influential observations could be related to the extreme drought, an event that in this intensity rather had one-time character. After exclusion of three observations, the all variables except *Interact_DrTurnHP* became more significant, the *Temp* coefficient increased by a small margin and the R^2 was slightly reduced. Based on a graphical analysis and White's test we found evidence of heteroscedasticity, i.e. we cannot stay with the assumption of a homoscedastic error term. Therefore we employ White's heteroscedasticity consistent estimators for the standard errors. As the White's standard errors are even lower than the OLS standard errors, our t-values increase and the coefficients become more significant. Therefore we conclude that we do not find a case of severe heteroscedasticity in our data. Moreover, we do not find any signs of serious multicollinearity in our data.

⁸⁴ We performed a formal t-test in order to ensure that this sum of coefficients is significant.

⁸⁵ All other coefficients are to be interpreted in a similar fashion.

⁸⁶ The corresponding tests can be found in detail in the Appendix B.

⁸⁷ This was done based on scatterplots showing the relation between our dependent and one of the explanatory variables, Mahalanobis distances and DfBetas.

By using a Durbin-Watson d-test we found evidence of positive autocorrelation, i.e. the error terms are positively correlated over time.⁸⁸ As a result, our OLS estimators are still linear and unbiased but not efficient anymore, meaning that they do not have the smallest variance.

The Jaque-Bera test indicated that the error term in our analysis does not follow a normal distribution. However, the Central Limit Theorem expresses that if a random sample of variables is selected from any population, then for large samples the sampling distribution of the mean tends to approximate the normal distribution. Given the large number of observations, 466, we are considering the theorem is likely hold. Therefore, we stay with the assumption of a normally distributed error term.

6 Discussion

In this section first our regression results will be interpreted. We examine the variables used in the analysis to determine what the coefficients imply. The focus of the subsections is the turnover variable, as it is a proxy for market integration and therefore most relevant for our research question. The interpretation of the turnover variable will be split up according to the non-drought and drought periods. We will also qualify the results and interpretation through discussion of the limitations of our analysis.

6.1 Interpretation

The empirical analysis yields a reasonably high R^2 . Having obtained significant coefficients with the expected sign, we are reassured that our model is a sound representation of reality, fits well theory and abides by previous modelling approaches of prices in the Nordic electricity market. We can therefore draw conclusions from the coefficients obtained.

6.1.1 Interpreting Demand and Supply Variables

For both *Temp* and *Water* the coefficients yield the expected sign. This is in line with previous research and our intuition. Having dropped *IP* and *Daylength*, temperature is the only variable representing the demand side in our model.

Water reservoir levels show a negative relationship with the system price, as expected. This result fits our intuition and shows that the concept of ‘value of water’ works in reality. An increase in reservoir levels reduces the opportunity or marginal cost of producing electricity so that as more electricity is supplied at a given price, the system price falls. The significance also reflects the high importance that hydropower has for the Nordic market, although it is – according to the standardized coefficients – the least important variable in our model.⁸⁹

According to our model results, the concentration ratio is one of the main determinations of system price. Concentration, to our knowledge, has not been explicitly used as an explanatory variable in empirical analyses on the Nordic electricity markets. In modelling approaches like

⁸⁸ Autocorrelation hints at a specification bias, implying that we have not included all relevant variables, or an incorrect functional form. It may also arise due to data smoothing, like using the HP-Filter we employed.

⁸⁹ The parameter stability test indicates that the coefficient for water levels is more negative in the second period. We could not confirm this result for the drought period because the interaction term with *Drought* was not significant in the final regression model.

Amundsen et al. (1998), which compare competitive with Cournot equilibria, market structure is addressed, but concentration measured as market shares in generation capacities has not been used in empirical studies.

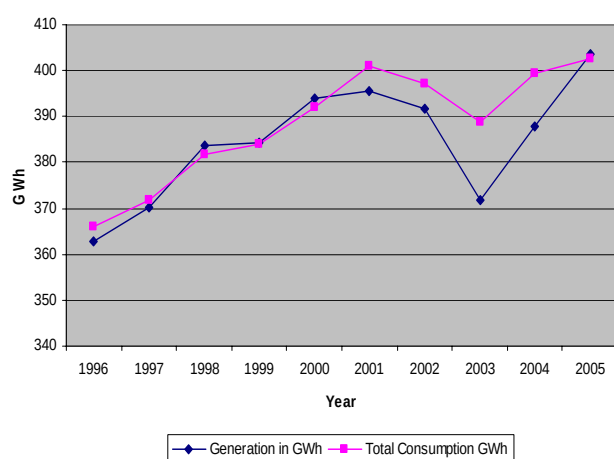
The analysis confirms a positive relationship between concentration in adjustable generation capacity and Elspot price. The underlining dynamic is that concentration allows for the possibility of the exercise of market power, i.e. to raise prices above competitive levels, especially through the potential to adjust short run supply quantities in a flexible manner.⁹⁰ We describe the manner in which market power may be exercised in the hydro generation field later in this section. In addition, a higher industry concentration makes collusion among the actors more probable.⁹¹ A sequence chart in Appendix A.2 shows the variation in concentration over the period, from 1996 to 2005. We note with interest the significant drop in concentration in 1998.

6.1.2 Interpretation of the Turnover Variable- Two Market Regimes

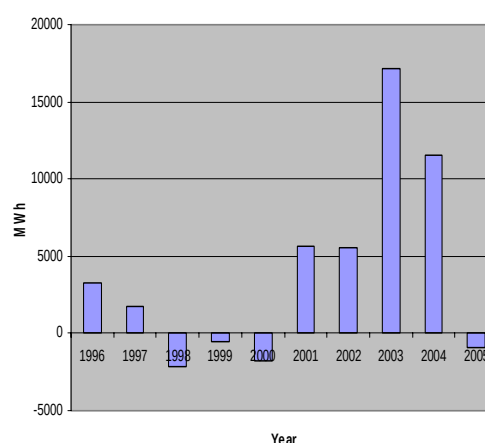
Due to the fact that the turnover variable is not stable over time, we interpret it in two distinct periods, non-drought and drought. We identify two separate market regimes over the period that reflect different states of the economy. In the first regime, during the non-drought period, the growth in demand and consumption is met with sufficient electricity supply. In the second regime, the drought period, the growth in demand is unable to be met with sufficient supply due to the severe supply shock caused by the drought in hydropower production. We note that such an extreme drought is a singular, stochastic event. This notion is supported by empirical evidence presented in the graphs below. By 2005 the market was again characterized by negative excess demand and sufficient levels of electricity generation. Therefore, our observed market integration effect is likely to persist over time, in absence of exogenous shocks such as that witness during the drought.

The graphs below show a time series of total generation and consumption in the Nordics during the years 1996–2005 on the left and the ‘excess demand’, i.e. consumption that could not be met by generation in the Nordic countries, on the right.

Graph 10: Generation and Consumption 1996 - 2005



Graph 11: Excess Demand 1996 - 2005



Source: Nordel

⁹⁰ See Finnish Competition Authority (2006)

⁹¹ See Cabral (2000)

From these graphs we see that between 2001 and 2004 there was a severe supply shock. Electricity generated in the Nordics was significantly lower than the consumed capacity. Excess demand increased heavily in these years, reaching its highest point in 2003 with consumption being about 1700 MWh higher than electricity generated. We also note that excess demand returned to negative levels in 2005 indicating the end of the drought period and its characterisation as a singularity.

Having identified these two regimes that reflect different market conditions, we now begin with the discussion of the turnover variable during the non-drought regime.

6.1.3 Interpretation of the Turnover Variable in the Non-Drought Regime

The turnover variable in the non-drought regime yields a negative relationship with the Elspot price. The expected effect affirms our hypothesis that an increase in turnover, or market integration, leads to a decrease in the system price. The fact that we cannot reject the null hypothesis of a negative relationship between market integration and wholesale prices does not imply this relationship exists in actuality, only that our hypothesis is met given the specific parameters established by our empirical strategy.

The results cannot identify the specific efficiency gains from integration that affect the Elspot price. By examining the efficiencies initially presented in section 4.2, the goal is to qualify their potential effects and indicate the more probable sources of the result. We present efficiencies that were probably not realized and subsequently, those that probably were.

Regarding the effect of integration on investment incentives from increased market transparency, Woo et al. (2003) offers evidence in a comparative study on different electricity markets that contradicts our argumentation. The paper finds that even with integration, there has been minimal development of new generation capacity in large part due to investor uncertainty. This actual finding undermines the theoretical consideration and should substitute our previous notions.

Considering the more efficient use of generation capacity, firms will have lower average cost as the amount of spare capacity needed to ensure supply security could be reduced in an integrated market. This should lead to lower wholesale prices. In a highly competitive environment where companies are under pressure to offer lower prices to the market, any average cost reduction will be passed on to the consumer. Given the oligopolistic structure and the existence of capacity constraints, as depicted in section 4.1.1, there may be a lack of competitive pressure on companies to pass on cost reductions.

There were expected efficiency gains from a more diversified generation technology portfolio through integration. It is probable that this effect was realized in the non-drought regime.⁹² Generation efficiencies arising from countries having different peak-demand times are cyclical, repetitive and therefore probably achieved. Efficient electricity wholesale consumers will have leveraged the difference in peak-demand, most obvious between Sweden and Finland.

⁹² This efficiency will vanish if the portfolio is undiversified.

Another likely realized efficiency is the reduction of transaction costs, as export and import charges were eliminated in the integrated market. There is no countervailing evidence that contradicts our confidence in this effect.

From the sequence chart of the concentration variable⁹³, one can observe a sharp drop in concentration in 1998. This indicates that with the integration of Finland into the Nordic market, the potential efficiencies induced by a lower concentration, or more competitive market structure. However, since the concentration ratio at the end of the period was only slightly lower than that in 1996, the intensity of these efficiencies is likely to be weak over the period.

The turnover variable during the non-drought regime most likely yielded the expected, negative, sign, due to the effect of efficiencies arising from the diversification of the generation technology portfolio, and the reduction in transaction costs in the market. Efficiencies from a more transparent market, efficiencies that led to a lower average cost for firms on the market, and efficiencies from a reduction in concentration are not likely candidates for the reason behind lower system prices following market integration.

We conclude that at the wholesale level there are indications of efficiency gains that have been realized through an integration of different markets. This interpretation is supported by the fact that integration of electricity markets is occurring across Europe. One example is the planned market coupling between the Danish and the German market scheduled for 2008. The main rationale behind it is that it will further improve market efficiency.⁹⁴

6.1.4 Interpretation of the Turnover Variable in the Drought Regime

From our final model we see that the turnover variable during the drought regime has a weak yet positive impact on wholesale prices. We need to examine the reason for the result, as integration seems to lead to higher prices during this period. Possible causes for our result stem from the negation of probable efficiencies described above, the use of market power, risk aversion and the role of imports.

There is no evidence to contradict the proposition that the efficiencies generated through lower transaction costs prevailed during both regimes. However, the potential efficiencies from a more highly diversified technology portfolio may not hold. As hydropower resources were curtailed during the drought, the share of hydropower in the technology portfolio of the Nordics was diminished. This is equivalent to less variety in generation sources, limiting the diversity of the portfolio.

We found two contradictory papers that posit drivers for the price increase during the supply shock other than the negation of efficiencies. Amundsen and Bergman (2006) argue that the scarcity of water was responsible for higher prices. They find no use of market power using a simulation model (PoMo). Von der Fehr et al. (2005) attribute high prices to tight market conditions, i.e. a reduction in excess capacity, and an increase in concentration via horizontal and vertical mergers.

⁹³ See Appendix A.2

⁹⁴ See European Energy Exchange AG (2007)

Due to the predominance of hydropower on the market, the need to account for the effect of the drought in our analysis was clear. Therefore, Nordic water reservoir levels were included in the regression. If the price increase was caused solely by the scarcity of water, as forwarded by Amundsen and Bergman (2006), the water variable should have captured the effect on price induced by a supply shortage. Therefore, the turnover variable during the second regime seems to capture some other effect- an omitted variable not included in our regression analysis. The omitted variable provides for a positive relationship between turnover and price.

A possible reason for the turnover result is that during the drought regime hydro generators further limited their supply of hydropower when the water levels were low. This could be identified either as the exercise of market power or strong risk aversion among the generators. Since a hydro producer can save water reservoir contents for future use, it can time the market in order to maximize profits. A hydro producer can exercise market power not only by restricting the total level of its production but also by scheduling its hydro production. If the price of electricity is expected to be higher in the future, it is in the generator's interests to limit generation today and instead produce in the future when electricity prices are higher.⁹⁵ An expected drought provides justification to withhold capacity due to the high probability of sustained water shortages.⁹⁶ We should state that Amundsen and Bergman (2006) do not find market power and highlight the difficulties in timing the market because information about the future is limited.

As an alternative explanation, Amundsen and Bergman (2006) see risk aversion among generators as a possible reason that could partly explain price rises. Risk averse generators are overly anxious to reduce hydropower production when the risk of running out of water before the spring period is perceived to be high. This reduction of output leads to higher market prices.

A second influence that may have generated a positive correlation between turnover and system price may be expensive imports. For satiating the demand on the market, the electricity generators imported electricity, mainly from Russia, Germany and Poland.⁹⁷

Even though in general electricity prices in the countries mentioned were not higher than in the Nordics⁹⁸, bottlenecks created by limited cross-border transmission capacities and import charges could have raised wholesale prices.⁹⁹ When examining the interconnection capacity between Finland and Russia, for example, there are several charges on imports to the Nordic countries- a capacity fee, a use-of-grid fee, a market border fee, an ETSO¹⁰⁰ fee and a peak-power fee.¹⁰¹ In addition, the campaign in Finland to substitute domestic condensing power production for imported electricity, adds credence to the notion that import prices are more expensive than domestic production,¹⁰² since importing electricity seems not to be an economically profitable option in the long run. However, during the drought regime, a time of

⁹⁵ Compare Deng (2005)

⁹⁶ An assumption to allow for this behavior is that competing generators will not supply the hydropower needed to satiate the excess market demand.

⁹⁷ Numbers of total imports into the Nordic region were obtained from Nordel's annual statistics. See <http://www.nordel.org/Content/Default.asp?PageID=213>.

⁹⁸ See Dodsworth et al. (2002)

⁹⁹ Here it is assumed that these costs are passed on to wholesale consumers.

¹⁰⁰ ETSO stands for European Transmission System Operators, see <http://www.ets-net.org/>.

¹⁰¹ The exact fees can be checked on http://www.fingrid.fi/portal/in_english/services/cross-border_services/power_transmission_on_russian_connections/.

¹⁰² See the press release of the Finnish Energy Industries:

<http://www.energia.fi/en/pressreleases/energy%20year%202006%20electricity.html>

a severe supply shock, excess demand required imports. Therefore, expensive electricity imports in the years of drought may have been the reason for the correlation between higher prices and turnover.

6.1.5 Interpretation Conclusions

In conclusion, the temperature, water and concentration variables yielded the expected results. The turnover variable created some interpretational challenges since the coefficient provided the expected sign in the non-drought period, and the opposite sign in the drought period. The drought regime is characterized by unique circumstances, namely a severe supply shock. Therefore, in the final model set-up we control for the impact of the drought and arrive at our expected result. This affirms our hypothesis that an increase in turnover or market integration leads to a decrease in the system price. We should note that all of our interpretations are made with some uncertainty given the potential threats to internal model validity presented in the robustness section above. However, the threat is based solely on the potential of positive autocorrelation.

The expected turnover sign was driven by the efficiencies outlined in section 4. We have examined the potential reasons for the result of the unexpected sign. The scarcity of water is an unlikely reason since this supply shock should have been captured by our water variable. We have offered three alternative explanations for the result, the exercise of market power, risk aversion and expensive imports. The exercise of market power seems an unlikely candidate, as other studies have been unable to identify its use. The more likely candidates are risk aversion and the cost of imports during the drought.

6.2 Limitations

A Master's thesis is completed under certain time constraints and this has implications for the scope of this study. Potential extensions that could not be realized in this paper like an analysis of area prices or an examination of retail prices will be returned to in the last section when talking about suggested topics for further research. Critically evaluating our work, we can identify potential limitations in our literature, data and methodology.

It is important to note that there is no direct literature on our research question. We know of no study that attempts to draw a direct link between integration and the effect on wholesale electricity prices in the Nordics. Although this makes our study one of great interest for an involved reader, there may be drawbacks from having to combine research findings from various areas including the gas market, the American market, and general studies on market structure and price. One obvious disadvantage is that these studies do not account for the idiosyncrasies of the Nordic market.

One of the more serious limitations of our paper is the lack of availability of specific data. For example, imports and exports figures on a weekly basis could have possibly provided us some further insight about the effect of integration on system prices during the drought period. Data on consumption on the Nord Pool Spot market, which would have been quite useful in determining the exact relationship between price and demand, is available only after January 2000. To extend the entire scope of the natural experiment we would have also liked to have observed comparable Swedish wholesale electricity prices pre-integration so that we had two steps to the integration process- one where Sweden joined Norway and then when Finland joined Norway and Sweden.

In some cases even if the data was available the authorities responsible for collecting the data were unwilling to supply the information free of charge. For example, data on precipitation, which might have contributed to a more thorough paper, was too expensive to procedure.

We also faced issues of confidentiality. Competition authorities in the Nordic countries had information on market shares, even in the field of adjustable capacity, and more general information on generation capacities of individual players on the market. However, due to confidentiality issues, we were forced to obtain this information from the annual reports, and create our own data on market shares. Therefore, the verification of the data was not carried out by an independent source, but left at the discretion of the companies.

There is a serious shortcoming from a methodology perspective of not including Denmark. The integration of the Nordic markets should evaluate the effect of integration of every market, and the distinctive generation technology portfolio held by Denmark could demonstrate far more clearly the efficiency gains discussed above through their ramifications on system price. Our decision was a result of practical and theoretical considerations. Data on Denmark was far too expensive, and much of the data we found for other countries was unavailable for Denmark.¹⁰³ In addition, there were significant transmission issues between Denmark and the rest of the Nordic countries, which would have had to be taken into consideration.¹⁰⁴ Although we believe that one step of integration should be sufficient to detect an effect on market integration, the omission of Denmark is still a limitation of our study.

Another limitation of our study could be the aggregation and disaggregation of data for our various variables. In some cases, for example with the temperature variable, we believe we significantly refined the aggregation technique undertaken in previous studies, for example by Hjalmarsson (2000), to achieve a more sophisticated variable, in that it more accurately weights the demand for electricity. However, the aggregation of industrial production may have been one reason for its lack of significance in our results, since we expected such a clear indicator of demand to have more explanatory power.

We also might have encountered simultaneous causality between our independent variable and our explanatory variables. Simultaneous causality bias arises when, in addition to the causal link of interest from the independent variable to the dependent variable, there is a causal link from the dependent variable to the independent variables.¹⁰⁵ This may have been the case for the turnover variable, although we think to at least partly have cured this problem by concentrating on the linear trend of the series.

¹⁰³ As an example, no major electricity generator in Denmark provided information which disaggregated generation technology into adjustable and non-adjustable capacities, and into production in East and West Denmark. This information was necessary since the two parts of Denmark joined Nord Pool at different times.

¹⁰⁴ We note that as we are just analysing the system price of Nord Pool, transmission constraints do not directly matter. But still we believe that these significant constraints will lead to different strategic behavior by companies.

¹⁰⁵ As mentioned before, this simultaneous causality makes the independent variable correlated with the error term in the population regression of interest.

7 Conclusions and Suggestions for Further Research

In our study we answer the research question- has market integration of the Nordic electricity markets had an effect on wholesale prices. We understood integration as an increase in volume traded on the Nord Pool spot market. We performed a regression analysis for exploring this causal relationship using weekly data from 1996 to 2004 with 466 observations.

We find that market integration has an effect on wholesale prices on the Nordic markets – size matters! Increasing integration leads to a decrease in prices due to efficiency gains. The most probable drivers behind these gains are the diversification of the generation technology portfolio and the reduction of transaction costs. As an additional result, concentration in adjustable generation capacity has been shown to have a significant impact on wholesale prices.

The thesis provides some straightforward policy implications for both the Nordics and Europe, as well as highlights the areas where further research could be beneficial. Regarding Nordic electricity policy, the identified effect of market integration on prices calls for more investments in cross-border capacities so that the traded amount between countries is not limited due to transmission constraints. This should allow for a sustained effect of market integration since market conditions may tighten in absence of sufficient cross-border investments. In addition, companies involved in the generation of thermal and nuclear power should be incentivized to build increased generation capacity in these areas to increase the diversity of the energy generation portfolio. This should limit the effect on prices caused by a supply shock, which affects a particular energy source.

Applying our main results to Europe, this paper offers support for the current drive towards a single European electricity market. The paper demonstrates that there are efficiency gains to be achieved via an integration of national markets. Highlighting the efficiency gains from combining different generation sources for electricity, it may be that policy should focus on integration of markets that have different resources endowments for use in power generation.

Furthermore, as stated in Houmoller (2007), cross-border trade, through additional investment in transmission capacities and appropriate congestion management mechanisms, is crucial for the development of one single market. This is in line with our findings as cross-border transmission constraints lead to a lower amount of electricity traded. Establishing new, and increasing the existing, cross-border capacities should therefore be a high priority.

Suggestions for further research can be derived from our policy implications as well as from our limitations. To our knowledge our study was the first to examine and detect a market integration effect on spot market electricity prices. Regarding the Nordic electricity market, this effect should be investigated in more depth by first looking at area prices, which would take into account transmission issues and through an analysis of the impacts on the retail level. Furthermore a similar study on the effect of integration on the clearing markets for bilateral contracts would provide a more holistic view of electricity price development within an increasingly integrated electricity market. For research on competition, besides looking at standard concentration measures like market shares, partial ownership relations among players, even with small stakes, should be examined as these tend to increase horizontal

market power and therefore could increase the price of electricity.¹⁰⁶ Taking a European perspective, research should further evaluate the effects of limited cross-border transmission capacities and provide theoretical approaches on how to incentivize companies to invest more in such capacities.

¹⁰⁶ Amundsen and Bergman (2006) This concentration via ownership relations is difficult to detect for competition authorities, as a very detailed analysis of the shareholding of each company is necessary. An attempt to do so by the Norwegian competition authority led to the conclusion that that the national electricity market is considerably more concentrated when accounting for ownership relations compared to standard concentration measures. See Norwegian Competition Authority (2007)

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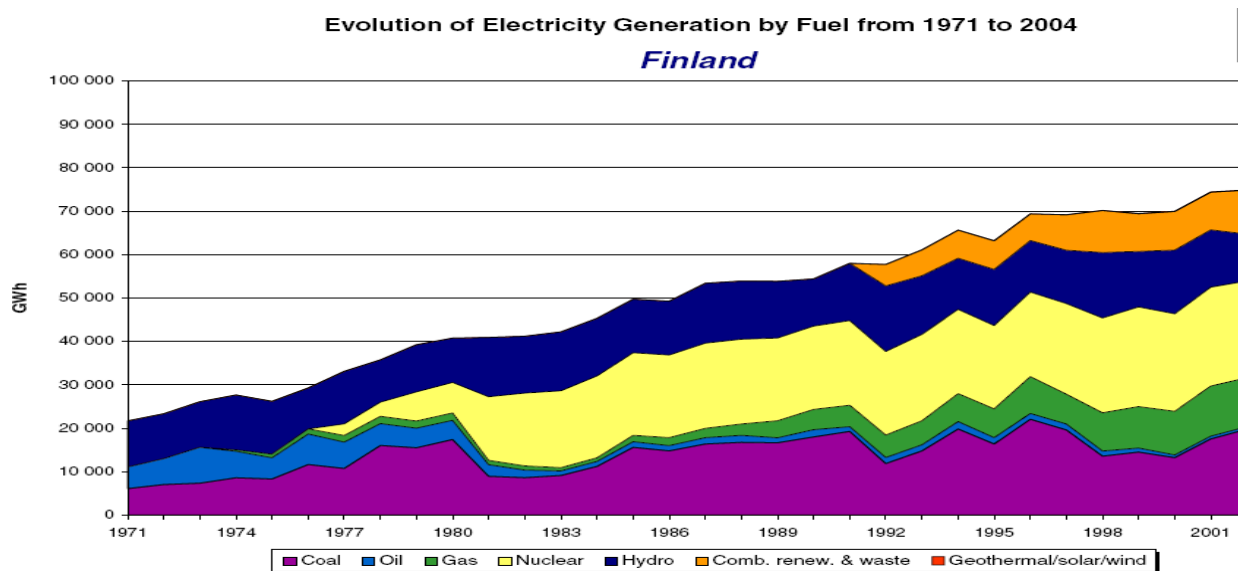
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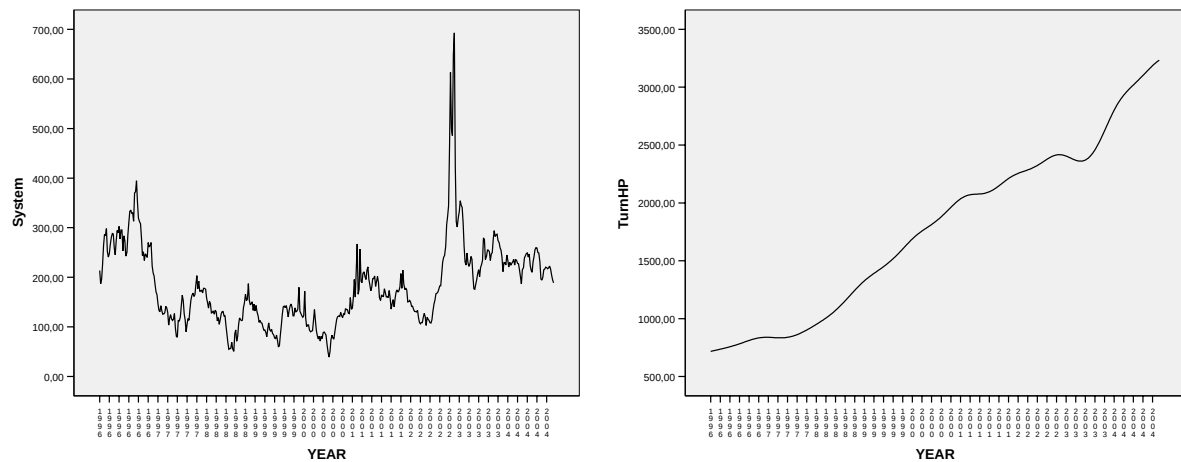
9 Appendix

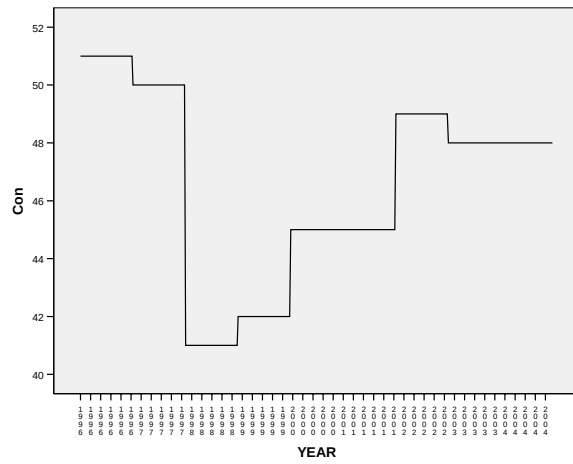
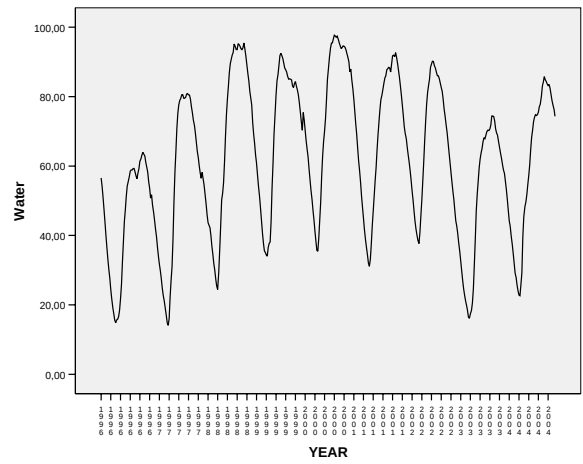
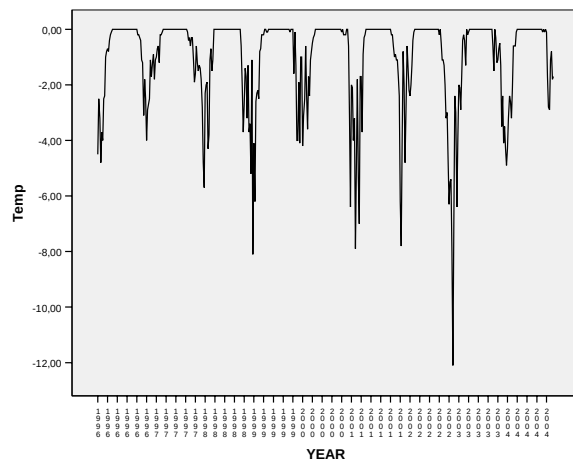
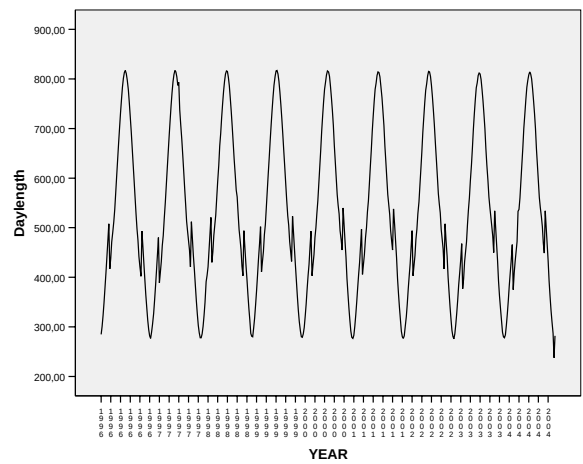
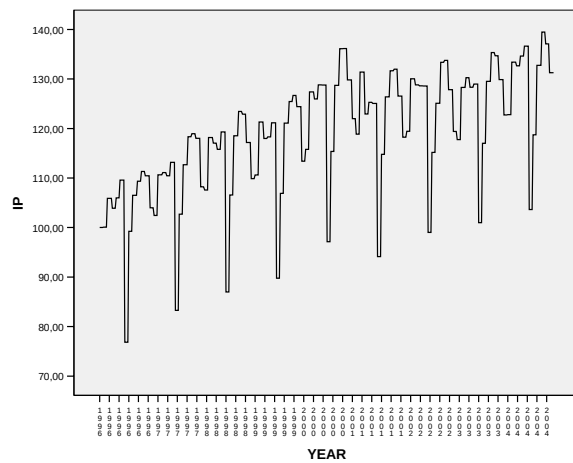
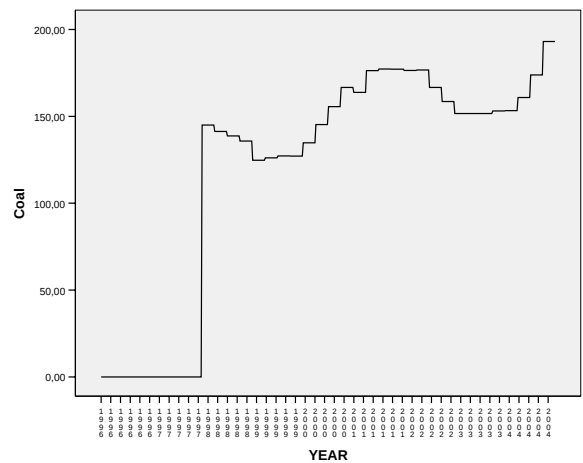
A) Section: Empirical Analysis

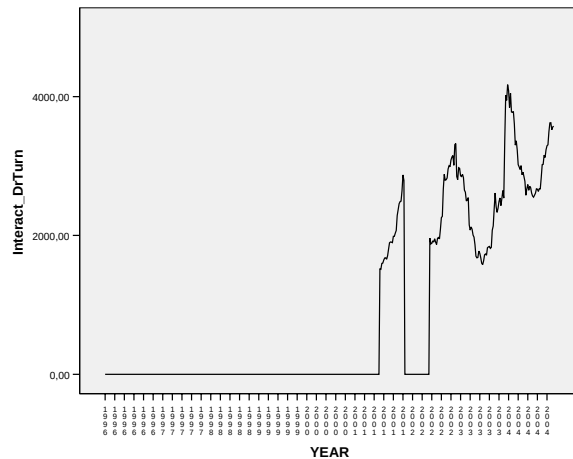
A.1 The evolution of electricity generation in Finland 1971 -2004



A.2 Sequence charts of all variables introduced in the empirical section:







A.3 Table of simple correlations

Correlations								
		System	Con	Water	Temp	Daylength	Coal	TurnHP
System	Pearson Correlation	1	,515**	-,328**	-,374**	-,268**	-,133**	,206**
	Sig. (2-tailed)		,000	,000	,000	,000	,004	,000
	N	468	468	468	468	468	468	468
Con	Pearson Correlation	,515**	1	-,309**	,041	-,009	-,497**	,050
	Sig. (2-tailed)	,000		,000	,371	,839	,000	,281
	N	468	468	468	468	468	468	468
Water	Pearson Correlation	-,328**	-,309**	1	,116*	,034	,307**	,156**
	Sig. (2-tailed)	,000	,000		,012	,466	,000	,001
	N	468	468	468	468	468	468	468
Temp	Pearson Correlation	-,374**	,041	,116*	1	,605**	-,069	-,047
	Sig. (2-tailed)	,000	,371	,012		,000	,135	,306
	N	468	468	468	468	468	468	468
Daylength	Pearson Correlation	-,268**	-,009	,034	,605**	1	,008	-,021
	Sig. (2-tailed)	,000	,839	,466	,000		,861	,655
	N	468	468	468	468	468	468	468
Coal	Pearson Correlation	-,133**	-,497**	,307**	-,069	,008	1	,791**
	Sig. (2-tailed)	,004	,000	,000	,135	,861		,000
	N	468	468	468	468	468	468	468
TurnHP	Pearson Correlation	,206**	,050	,156**	-,047	-,021	,791**	1
	Sig. (2-tailed)	,000	,281	,001	,306	,655	,000	
	N	468	468	468	468	468	468	468
IP	Pearson Correlation	,062	-,108*	,055	-,037	-,280**	,583**	,639**
	Sig. (2-tailed)	,178	,020	,232	,426	,000	,000	
	N	468	468	468	468	468	468	468

**-. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

A.4 Testing for parameter stability

We use dummy variables in order to test for parameter stability, i.e. testing if we can use the same regression model for describing both the first half and the second half of the estimation period. The dummy variable will be set equal to zero for the first half of the time period. The test approved that our parameters are not stable over time. The relevant SPSS output is:

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-140,446	69,007		-2,035	,042
	TurnHP	-,064	,015	-,560	-4,367	,000
	Con	8,090	1,199	,318	6,750	,000
	Water	-,155	,185	-,041	-,834	,405
	Temp	-9,341	2,667	-,188	-3,502	,001
	Dummy	29,478	145,744	,176	,202	,840
	Interact_DTurn	,126	,019	1,848	6,597	,000
	Interact_DCon	-3,785	3,160	-1,065	-1,198	,232
	Interact_DWater	-,802	,262	-,343	-3,064	,002
	Interact_DTemp	-13,102	3,335	-,228	-3,929	,000

a. Dependent Variable: System

A.5 Inclusion of Interaction terms of *Drought* with *Water* and with *TurnHP* in the regression model

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-221,419	46,596		-4,752	,000
	TurnHP	-,024	,006	-,208	-3,867	,000
	Con	9,328	,890	,367	10,486	,000
	Water	-,543	,146	-,145	-3,710	,000
	Temp	-15,232	1,635	-,307	-9,314	,000
	Interact_DrTurn	,033	,005	,502	6,202	,000
	Interact_DrWater	,027	,178	,011	,153	,878

a. Dependent Variable: System

B) Robustness Tests

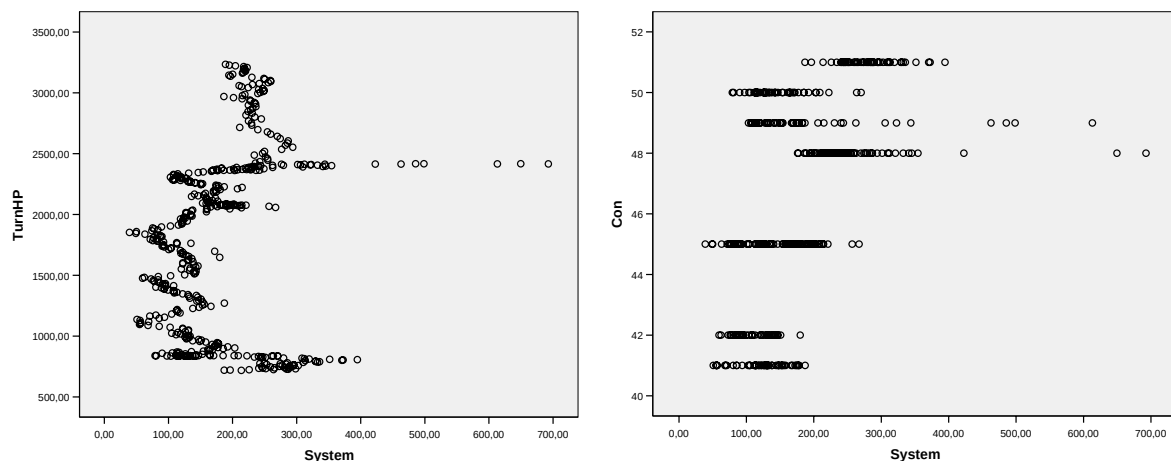
In order to check the robustness of our results, we performed several robustness tests. Below you find a short description of the graphical analyses and/or the testing procedures regarding:

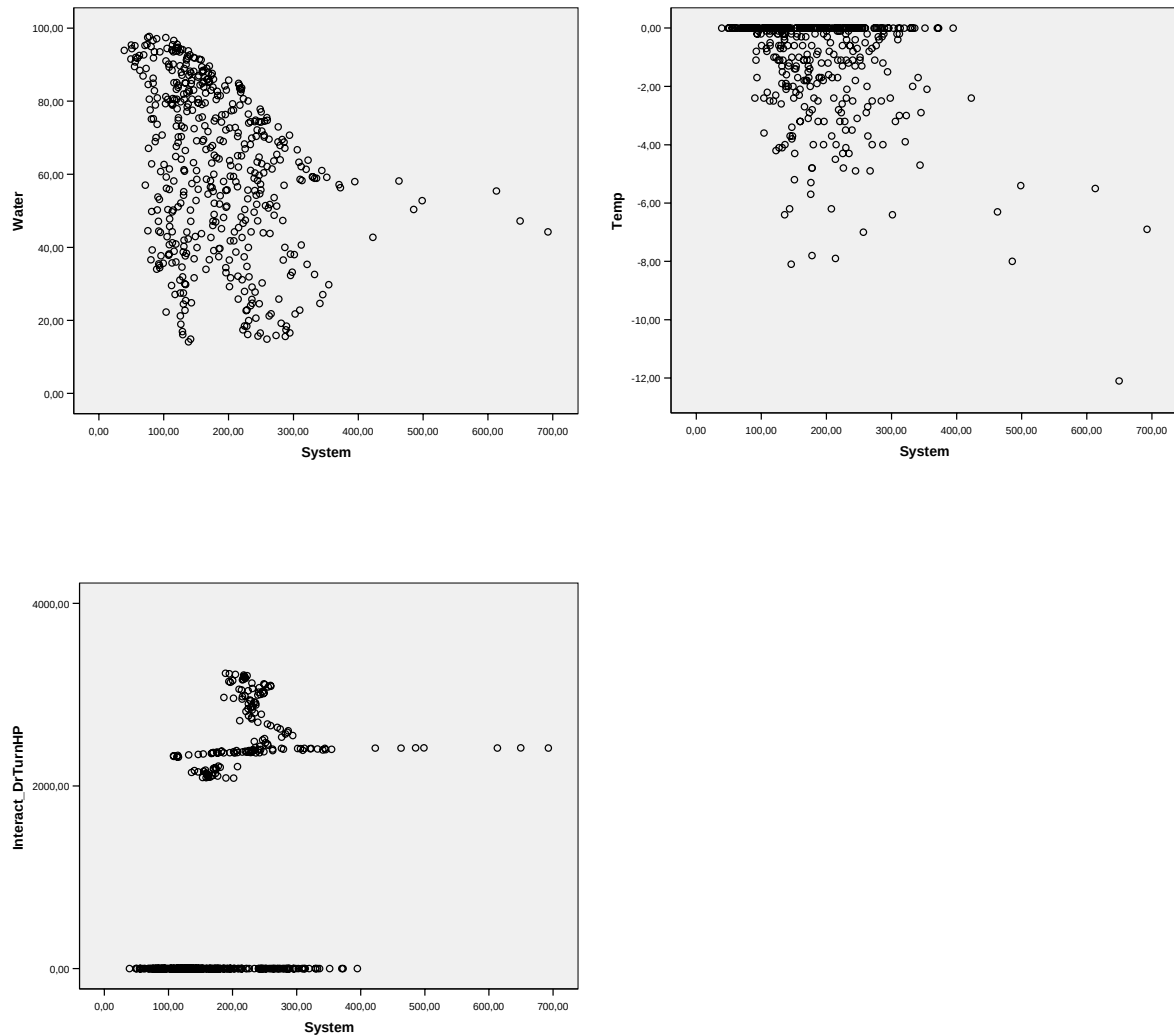
- Outlier / Influential observations
- Multicollinearity
- Heteroscedasticity
- Autocorrelation
- Normality

B.1) Outlier / Influential observations

In this section we will first look at outliers and influential observations that may have a large impact on our estimated coefficients and then decide in a second step whether it makes sense to exclude certain observations from the data set.

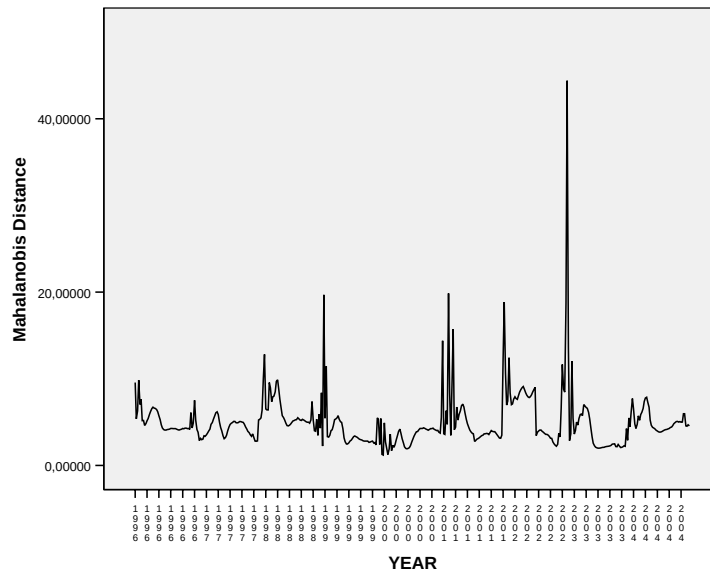
As a first approximation, we use 5 scatterplots which each show the relation between our dependent and one of the explanatory variables.





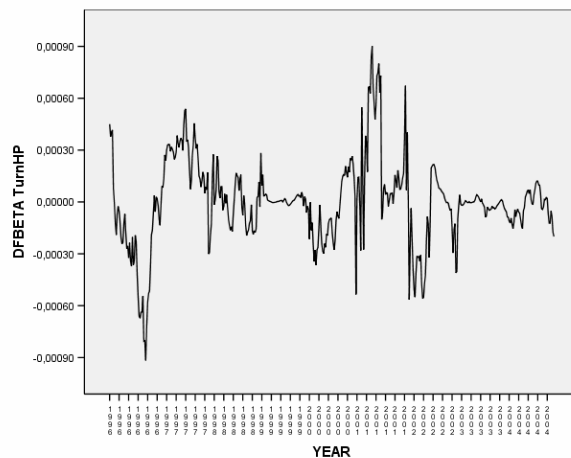
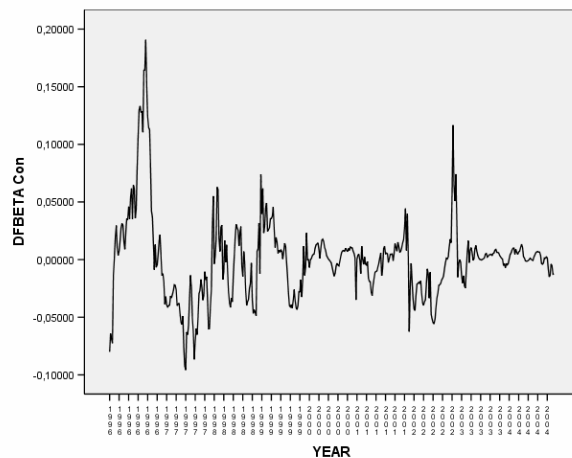
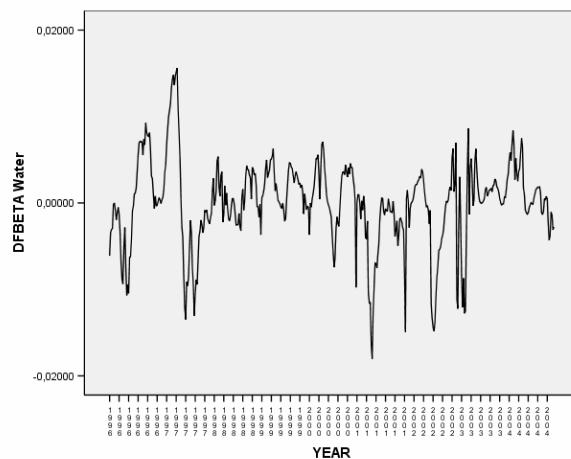
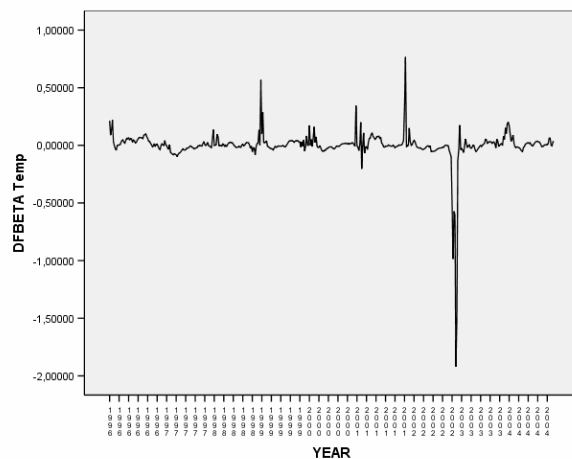
Basically all the scatterplots indicate that there are 3 outliers, i.e. an observation that deviates from the general pattern, that show high values on the system price variable.

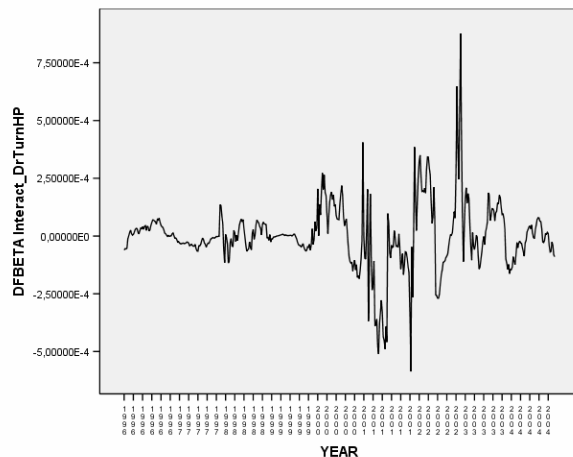
After this first indication of outliers and potentially influential observations, we will now look at the Mahalanobis distance and the DfBeta values for our explanatory variables for gaining further insights. The Mahalanobis distance measures how much an observations' values on the explanatory variables differ from their averages, their center of gravity. This plot is useful in detecting outliers in our model as high values hint at a high influence on our estimated coefficients.



The sequence chart indicates that we find extreme values on one or more explanatory variables two (maybe three) observations at the beginning of year 2003, namely observations 365 and 366 that are the first two weeks. Those observations may have a high influence on the regression coefficients.

In the next step, for each of our explanatory variables and the intercept we analyze the DfBeta values which measure the change in the regression coefficient which would result from the exclusion of a particular observation.





We see the highest DfBeta for the temperature variable with a value of -2 at the observation number 365, which also showed up significantly in the Mahalanobis distances. All other DfBetas are comparably small. From this analysis we concluded that it may make sense to exclude the two influential observations that were highlighted by Mahalanobis distance and the DfBeta. This was done to get more general regression results if we can relate them to events that have one-time and non-recurring character. The drought period in 2002/2003 seems to be such an event.

Re-running the regression we see that we get a slightly lower R^2 but at the same time all coefficients except the interaction term become even more significant. The coefficient value of temperature is the only one that increases by a larger amount. We therefore keep the data set with 2 observations excluded.

B.2) Multicollinearity

We do not find any indication of multicollinearity in our final model: as shown in the SPSS output below, we see neither high pairwise correlations between coefficients (except the one between *TurnHP* and *Interact_DrTurnHP* which should be assumed), quite high tolerance values and low variance inflation factors (VIF).

Coefficients ^a								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-200,462	43,132		-4,648	,000		
	TurnHP	-,026	,006	-,244	-4,405	,000	,321	3,118
	Con	9,001	,828	,383	10,864	,000	,793	1,262
	Water	-,595	,117	-,172	-5,074	,000	,857	1,167
	Temp	-14,206	1,553	-,291	-9,147	,000	,976	1,024
	Interact_DrTurnHP	,035	,004	,551	9,723	,000	,307	3,255

a. Dependent Variable: System

Coefficient Correlations ^a							
Model		Interact_DrTurnHP	Temp	Water	Con	TurnHP	
1	Correlations	Interact_DrTurnHP	1,000	-,006	,035	-,326	-,816
		Temp	-,006	1,000	-,140	-,091	,039
		Water	,035	-,140	1,000	,300	-,138
		Con	-,326	-,091	,300	1,000	,207
		TurnHP	-,816	,039	-,138	,207	1,000
	Covariances	Interact_DrTurnHP	1,28E-005	-3,5E-005	1,47E-005	-,001	-1,7E-005
		Temp	-3,46E-005	2,412	-,026	-,117	,000
		Water	1,47E-005	-,026	,014	,029	-9,4E-005
		Con	-,001	-,117	,029	,686	,001
		TurnHP	-1,71E-005	,000	-9,4E-005	,001	3,40E-005

a. Dependent Variable: System

B.3) Heteroscedasticity

Testing for heteroscedasticity means testing if the variance for the error term is not constant over time. For detecting heteroscedasticity we first used a graphical analysis as an approximation. Therefore we plotted the residuals vs. the estimated dependent variable and each of the explanatory variables. Those plots indicated that the variance for the error term, especially for the variables *TurnHP*, *Con* and *Temp*.

After this first approximation by a graphical analysis, in this subsection White's general heteroscedasticity test is used for testing for heteroscedasticity. We will use the White's test without cross-product terms in order to use it as a pure test of heteroscedasticity.¹⁰⁷

The test equation therefore is:

$$\hat{u}_t^2 = \alpha_1 + \alpha_2 \text{TurnHP}_t + \alpha_3 \text{Con}_t + \alpha_4 \text{Water}_t + \alpha_5 \text{Temp}_t + \alpha_6 \text{Interact_DrTurnHP}_t + \alpha_7 (\text{TurnHP}_t)^2 + \alpha_8 (\text{Con}_t)^2 + \alpha_9 (\text{Water}_t)^2 + \alpha_{10} (\text{Temp}_t)^2 + \alpha_{11} (\text{Interact_DrTurnHP}_t)^2 + v_t$$

The null hypothesis is that the error term is homoscedastic, i.e. all coefficients should be equal to zero. The test statistic we use is $n \cdot R^2$. We will reject the null hypothesis if the statistic is larger than $\chi^2_{crit.}$ with 10 degrees of freedom. The relevant SPSS output is:

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,422 ^a	,178	,160	5581,26202

a. Predictors: (Constant), Interact_SQ, Temp, Water, Con_SQ, TurnHP, Temp_SQ, Water_SQ, Interact_DrTurnHP, TurnHP_SQ, Con

b. Dependent Variable: RES_SQ

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3,1E+009	10	306690667,0	9,845	,000 ^a
	Residual	1,4E+010	455	31150485,76		
	Total	1,7E+010	465			

a. Predictors: (Constant), Interact_SQ, Temp, Water, Con_SQ, TurnHP, Temp_SQ, Water_SQ, Interact_DrTurnHP, TurnHP_SQ, Con

b. Dependent Variable: RES_SQ

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	239939,4	123440,7		1,944	,053
	TurnHP	26,801	8,711	3,257	3,077	,002
	Con	-12140,9	5579,969	-6,605	-2,176	,030
	Water	109,734	67,706	,405	1,621	,106
	Temp	1382,143	429,340	,361	3,219	,001
	Interact_DrTurnHP	-9,358	4,236	-1,891	-2,209	,028
	TurnHP_SQ	-,009	,003	-3,919	-3,156	,002
	Con_SQ	141,312	61,307	7,065	2,305	,022
	Water_SQ	-1,028	,581	-,450	-1,770	,077
	Temp_SQ	357,380	74,741	,523	4,782	,000
	Interact_SQ	,005	,002	2,622	2,433	,015

a. Dependent Variable: RES_SQ

With 466 observations our test statistic is 82.948.

Since this is bigger than the $\chi^2_{crit.} = 18.307$ so we reject the null hypothesis and regard the error term as heteroscedastic. This finding is also supported by the coefficients table: It shows

¹⁰⁷ See Harris (1995)

that several variables are significant at the 5% level. As a result, the OLS estimators are not the most efficient ones.

In order to cure the heteroscedasticity problem we use White's heteroscedasticity consistent estimators for our final model. The new standard errors are shown below, the coefficients are of course staying the same, as they are still OLS coefficients.

```
----- White's estimated standard errors -----
```

	b	se(b)	wse(b)	wt	wp
Constant	-200,46239	43,13200	33,60551	-5,96516	,00000
TurnHP	-,02568	,00583	,00519	-4,95066	,00000
Con	9,00059	,82846	,76078	11,83073	,00000
Water	-,59549	,11737	,10682	-5,57477	,00000
Temp	-14,20567	1,55306	2,26814	-6,26314	,00000
Int	,03484	,00358	,00288	12,10629	,00000

b = estimated coefficient, se(b) = OLS standard error

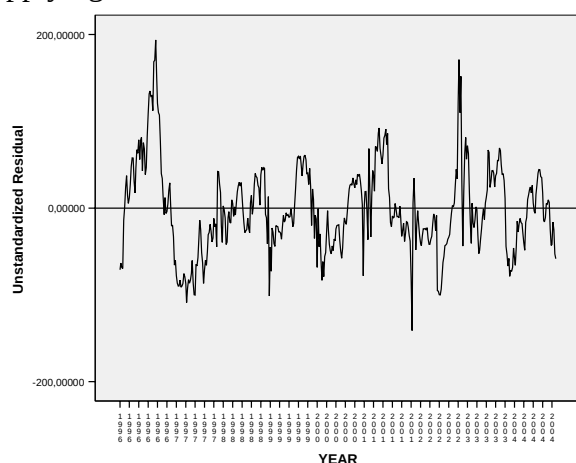
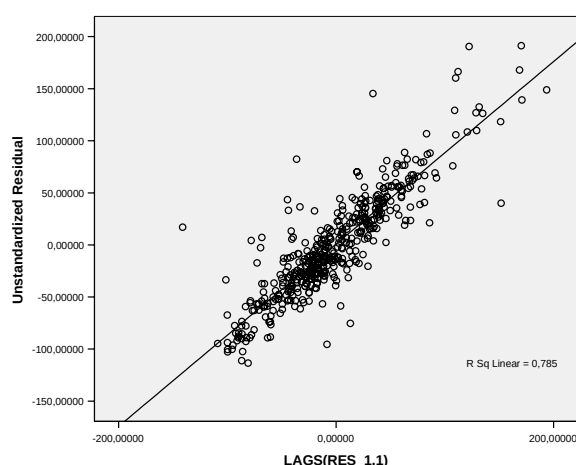
wse(b) = White's standard error, wt = White's t value, wp = White's p value

The White's standard errors are smaller (except the ones for Temp) than the OLS standard errors. This implies that our coefficients are becoming even more significant using a t-test. We therefore conclude that our heteroscedasticity problem may not be too bad.

B.4) Autocorrelation

Another assumption of the classical linear regression model is that there is no autocorrelation between the disturbances.¹⁰⁸

From the sequence chart displayed below no clear conclusion regarding positive or negative autocorrelation can be drawn. If there was positive autocorrelation, we would expect rather few sign changes. In case of negative autocorrelation, we would expect a sign change of the residuals every day. Looking at the scatter plot of the residuals against the lagged residuals, a clear indication of positive autocorrelation can be identified. At the moment we cannot tell whether this positive autocorrelation is statistically significant. This will be determined by applying the Durbin-Watson d test.



¹⁰⁸ If autocorrelation is present, the OLS estimators will still be unbiased and linear but no longer efficient, i.e. have the smallest variance in the set of possible estimators. Hence, the usual t- and F-tests will no longer be applicable.

The Durbin-Watson d test can be used to detect first order autoregression in the disturbances. The d-statistic is computed by the formula shown below.

$$d = \frac{\sum (\hat{u}_t - \hat{u}_{t-1})^2}{\sum \hat{u}_t^2}$$

$$H_0 : \rho \leq 0$$

$$H_1 : \rho > 0$$

A d-statistic around 2 will indicate no autocorrelation whilst a d-statistic close to 0 will indicate positive autocorrelation. Above, we established the expectation of positive autocorrelation. We will therefore test the null hypothesis of no positive autocorrelation against the alternative hypothesis that there is positive autocorrelation. Given our model based on 466 observations and 5 explanatory variables we obtain $d_L = 1,718$ and $d_U = 1,820$ at the 5% significance level. The d-statistic for our sample is $d = 0,209$. The relevant SPSS output:

Model Summary^a

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,739 ^a	,547	,542	52,68682	,209

a. Predictors: (Constant), Interact_DrTurnHP, Temp, Water, Con, TurnHP

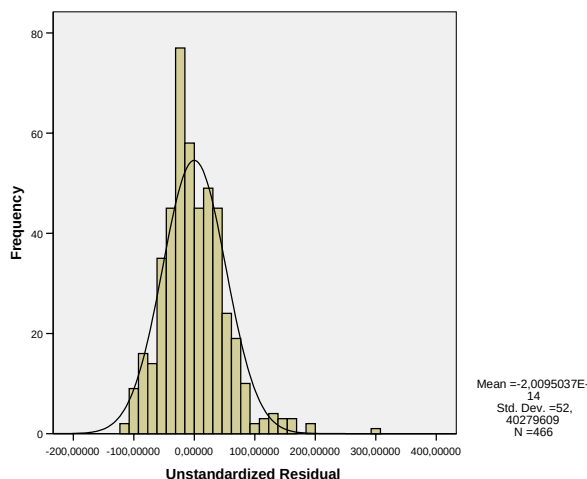
b. Dependent Variable: System

We conclude that there is statistically significant evidence of positive autocorrelation.

B.5) Normality

In the following section we will test whether the error term can be assumed to be normally distributed.

From the histogram of the residuals displayed below it is not possible to conclude whether the residuals can be assumed to follow the normal distribution. In general, the pattern of the residuals seems to be in line with the normal distribution. However, one outlier makes a clear-cut conclusion impossible.



The Jarque-Bera test is a more formal test for deciding whether the error term is normally distributed or not. We will test the null hypothesis that the error term is normally distributed against the alternative hypothesis that the error term is not normally distributed. The test statistic asymptotically follows the chi-square distribution with 2 df. We reject the null hypothesis if the test statistic is larger than the critical value.

$$JB = n \left[\frac{S^2}{6} + \frac{K^2}{24} \right]$$

$$JB \underset{asy}{\sim} \chi^2_{df}$$

The relevant SPSS output is:

Descriptive Statistics					
	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
Unstandardized Residual	466	,824	,113	2,250	,226
Valid N (listwise)	466				

As our observed value 151.031 is higher than the critical value of 5.992 we reject the null hypothesis of a normally distributed error term.