



DEPARTMENT OF POLITICAL SCIENCE
CENTRE FOR EUROPEAN STUDIES
(CES)

SIZE AND FLOW – DOES IT MAKE A DIFFERENCE?

Multinational electricity market integration and price effects at the Nordic electricity market

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Thesis:	Master thesis 30 hp
Program and/or course:	MAES - Master in European Studies
Semester/year:	Spring/2016
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Abstract

The liberalisation process and the (re)structuring of the electricity markets within Europe has been subject to extensive discussion during the last decade. A key concept in this discussion is the creation of multinational electricity markets. This thesis examines the process of multinational electricity market integration and price effects at the Nordic electricity market, Nord Pool. A theoretical model aiming to predict the effects of multinational electricity market integration is devised. The model defines the electricity spot price as the dependent variable and several market integration aspects as explanatory variables. The model is tested with an OLS-regression. The results presented indicate that multinational electricity market integration does have a significant effect on electricity prices at the Nordic power market, although not entirely as expected by the theoretical model. Increased flow of electricity across borders tends to *decrease* the spot price of electricity while the size of the electricity market in terms of increased volumes of trade tends to *increase* the spot price of electricity. Put differently, it seems as if increased volumes of trade do not per se benefit the customers in terms of lower electricity prices, rather the opposite. Instead, the results of this study points towards the importance of interconnectivity and transmission infrastructure.

Key words: Electricity price, market integration, market liberalization, Nord Pool, statistical method, time series analysis.

Word count: 14 944

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Abbreviations and key concepts

Transmission – The part of the electricity industry that transport electricity from production/import facilities to distributional networks and industrial consumers.

Transmission networks – High voltage network connecting production and distributional networks.

Distribution – The part of the electricity industry that delivers electricity to consumers.

Distributional networks – The networks connecting domestic customers to transmission networks.

Power exchange – Electricity market at which power is traded.

Nord Pool Spot market – Nordic market for power trading. Divided into a day-ahead market (Elspot) and an intraday market (Elbas).

Elspot market – Nord Pool Spot's physical day-ahead market.

Elspot system price – Electricity price determined at the Elspot market by the intersection of the aggregated supply and demand curves representing all bids and offers for the Nordic region.

Traded volumes – The amount of electricity transacted every week at the Elspot market.

Market participant – A person or a legal entity who has signed Nord Pool Spot's Participant Agreement.

Electricity generation – The process of generating electric power from other sources of primary energy.

1. Introduction

For most of its history, national electricity markets in the EU have been protected from foreign competition, tightly regulated and dominated by large, vertically integrated power companies. Over the last 15 to 20 years, however, this situation has changed and the electricity markets around Europe has experienced a rapid restructuring. Two of the most noticeable trends are the liberalization of electricity markets and the focus on multinational integration of different geographical electricity markets. The European electricity market liberalisation has been described as the world's most extensive cross-jurisdiction reform of the electricity sector (Pollitt and Jamasb, 2005:11). In addition to this, it is stated in the EU Electricity Market Directives (2003/54/EC and 2009/72/EC) that the EU has a clear intention of creating a single European market for electricity.

In Scandinavia, the process of electricity market deregulation, liberalisation and multinational integration started long before the EU announced its intentions to create a single European market for electricity. Norway was the first Nordic country to launch the liberalisation process of its electricity market, closely followed by Sweden and Finland in the middle of the 1990s and by Denmark in 1998. During the 1990s, far-reaching reforms were implemented in the Nordic countries and markets opened up to increase competition in both generation and supply. In addition to this, the national markets opened up for cross border trade and most notably, the first multinational power exchange was created. By the turn of the century, the four national markets had transformed into a (close to) fully integrated electricity market and over the years, the Nordic power exchange has grown both in terms of participants and amount of total trade of electricity going through the power exchange (Lundgren et al., 2008:1).

Following this rapid progress, the Nordic market is often described as one of the most developed electricity markets within Europe. Together with UK (which also started an electricity reform process in 1990) the Nordic countries are considered forerunners and ahead of time in relation to the Electricity Market Directives and the liberalisation process in the EU (Amundsen and Bergman, 2007:3383). However, in contrast to UK and many other regions in EU, the Nordic market has the special feature of being integrated by several national electricity markets. The Nordic countries are more or less alone in having an established reorganised multinational

electricity market. On the other hand, just because market institutions are common it does not necessarily mean that the Nordic electricity market is an integrated market with efficient price mechanisms.

This thesis reviews the process of multinational electricity market integration and in particular, the focus is upon the price effects at the Nordic electricity market, Nord Pool. An understanding of how the electricity price is affected by international market integration is of great importance, especially in the light of the commitment within Europe to create a single market for energy. Power exchanges are of particular interest since the creation of power markets can be seen as the ultimate step within the liberalisation process. A power exchange offers a competitive wholesale trading facility for electricity and the functioning of multinational power exchanges are therefore critical issues in the development of a successful European power market. An understanding of the effects of multinational electricity market integration could help both decision makers and market participants to build valid expectations about future electricity price dynamics.

This is how the rest of the thesis is organized: In chapter two, general background information about the Nordic electricity market and price formation is presented. Chapter three reviews previous literature on the relationship between market structure and price and the benefits of multinational cooperation in electricity markets. This paves the way for chapter four where the aim of the study and research question is presented. Building on top of previous research, a theoretical model of electricity price formation is presented in chapter five, followed by a definition of the study's hypothesis and econometric specification. In chapter six, the methodology of the thesis is presented and methodological problems are discussed. The chapter also accounts for the data used in this study. In chapter seven, the results of the study are presented in terms of descriptive statistics and regression results. Finally, chapter eight follows with a concluding discussion and suggestions for further research.

2. The Nordic electricity market

As previously mentioned, the Nordic countries have during the last decade experienced a rapid restructuring of their power markets. Starting with Norway in 1991, the Nordic countries have gradually liberalised their national electricity markets and step by step, merged their wholesale markets into a common Nordic electricity market. With this development, a new price mechanism for electricity price has been established and the functioning of the market has changed substantially.

2.1 Functioning of the Nordic electricity market

Today, the Nordic electricity market is divided into one physical market, Nord Pool Spot, and one financial market, NASDAQ OMX Commodities. In the financial market actors can hedge the system price for electricity through different financial instruments and trading of futures, forwards and options. The physical market Nord Pool Spot, is divided into two sub-markets; the Elspot market and the Elbas market. In short, Elspot is a cross border day-ahead market where hourly power contracts are traded for physical delivery the following day. The Elbas market on the other hand, is a cross border intra-day market where power is traded up to one hour before delivery. The market serves as a supplement to the Elspot market and the purpose is to secure the necessary balance between supply and demand in the power market for Northern Europe. Incidents may occur between the closing of the Elspot market and delivery next day. For example a nuclear plant could stop operating in Sweden or strong winds could cause higher power generation than planned in Denmark. In these situations, buyers and sellers are able to restore balance on the power market by trading power at the intra-day market close to real time. However the vast majority of the volume handled by Nord Pool is traded on the day-ahead Elspot market. For most part, balance between supply and demand is secured here. (Lundgren et al., 2008; Hjalmarsson, 2000). Henceforth, the Elspot market will be referred to in this thesis as the Nord Pool Spot market.

2.2 How electricity price is set

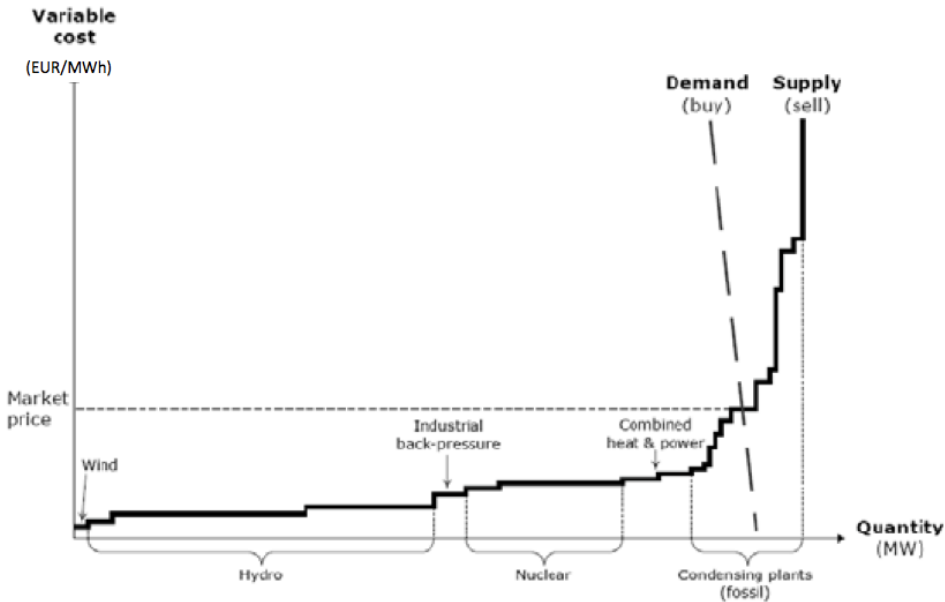
Following the market deregulation and multinational integration, the price of electricity is set at the Nordic power exchange, Nord Pool. This was combined with a new pricing principle for

electric power. Prior to the deregulation the national markets had been dominated by state owned utilities and different mechanisms for price setting. In Sweden for example, the pricing principle was dominated by average cost pricing. (Lundgren, 2012:3) In Norway, the electricity price was set in relation to the long run marginal cost of the previous year. Demand was not incorporated in the models and the market was generally characterized by compensations and subsidies, which gave limited incentives for utilities to be cost effective. After the deregulation, the pricing principle changed to marginal cost pricing. The purpose of marginal cost pricing in electricity markets is to differentiate consumption by time of use and geographical area so that costs can be transmitted to the consumers in a fair way. The basic idea behind the pricing principle is that price is set according to the cost of marginal production, i.e. the producer's cost of producing one extra unit of power (MWh). Consumers will be charged with the highest (marginal cost) price for all their demand. However, if consumers find the price too high they will reduce their demand. The price on the Nord Pool Spot market is therefore determined both by the aggregated sales bids of the producers *and* by the aggregated purchase bids of the consumers. (Pikk and Viiding, 2013) The supply bidders (electricity power generators) bid in how much they are willing to sell and at what price. If the market is working as expected, the generators bids should be reflected by their marginal cost of production (different for different power plants). The demand on the other hand, is determined by the consumers and their bids of how much electricity they need at the moment. The equilibrium price reflects the quantity where supply and demand intersect. (Lundgren, 2012:8) The market price, also known as the system price or the spot price of electricity, will be set at the marginal cost of the marginal bid.

Figure 2.1 The principle of price formation at the Nord Pool Spot market.

Variable cost of energy production

EUR/MWh



Comment: The figure illustrates how price is determined at the Nord Pool Spot market. The Y-axis represent the variable cost in EUR/MWh. The X-axis represents the power quantity produced in MW.

Source: Energy Market Inspectorate (2006:3)

It is important to note that following the Nordic electricity market reform, a distinction was made between electricity as a good and the service of electricity distribution through the transmission network. Whereas power supply and retail were set out to competition, distribution was left as a monopoly due to its special characteristics as a natural monopoly. Put differently, this means that people are free to choose which electricity supplier to buy their electricity from, just as they can choose the brand of the car they drive. But just as they are unable to choose a road construction contractor, they are unable to choose which network company to deliver the electricity. There is only one electricity grid, just as there is only one road system and the service of electricity distribution is thus a matter of domestic decisions and regulations. Power supply on the other hand, is considered a good that can be traded internationally.

In light of this, the electricity consumer's total cost for electricity consists of three parts; electrical energy, transmissions costs and tax. The only part of the total cost that is not regulated by the

governments of the Nordic countries is the electrical energy. The price of electricity is determined through competition on the common market for electricity, Nord Pool spot, which will be the continued focus of this thesis.

Finally, it is also important to underline that the spot price is calculated from a bidding process *before* any bottlenecks are discovered in the transmission network. This means that the spot price represents the electricity price for the entire region only under the assumption that no transmission constraint is binding. Whenever interconnector capacity constrains power flows, the Nord Pool market is divided into two or more “price areas”. According to Bask and Widerberg (2008:20), the bidding price from Nord Pool Spot is the price used in the entire region around half of the time. Although Amundsen, Bergman and Von der Fehr (2005:9) claim that these price differences were present for shorter periods only and the price difference between the spot price and the different area prices is often marginal.

3. Previous research

The aim of this section is to give an introduction to the subject of this thesis, namely, the relationship between multinational electricity market integration and electricity price levels. First, because the aim of the deregulation and integration of the Nordic electricity sector was to develop a competitive market, which would benefit the consumers in the Nordic countries, I review the literature on competitive market forms and the potential economic benefits of market integration. The purpose of these first subsections is to get a better idea of how the electricity price might be affected at a multinational market with increased competition. The final subsections are devoted to electricity price dynamics at the Nord Pool Spot and the relationship between multinational electricity market integration and electricity price levels.

3.1 Natural monopolies

Contemporary understanding of economy underlines the importance of competition in order to increase efficiency of production and lower the prices for consumers. To claim that competition is good for consumers and overall resource allocation is not too controversial. However, to establish competition is not as easy in every market. In some markets it may even be associated with great

difficulties. On a network-based market, such as the electricity market, it is neither practically nor theoretically optimal to allow several competing companies to build their own networks to deliver their goods to the consumers. In industries like the electric network industry there are increasing returns to scale in infrastructure; so large that duplication of the infrastructure is economically impossible or at least costly enough for infrastructural monopolies to be preferable. In economic theory, this is referred to as natural monopolies.

Since the network industry for transmission and distribution of electricity is characterized by natural monopolies, generation and supply are often highlighted as the potentially competitive segments of the value chain of electricity. In order to foster efficiency in the entire value chain of electricity, Amundsen and Bergman (2002) argue that mainly two types of regulations are needed. On the one hand, there is a need for traditional regulation of natural monopoly prices, service quality and investments. On the other hand, there is a need for regulation aimed at securing competition in generation and supply. One way to approach this has been to introduce liberalisation measures such as deregulation and multinational integration of the electricity markets, measures that will continue to be the focus point for this thesis.

3.2 Trade across borders and economic efficiency

Multiple benefits can be gained from integrated power markets. For this study a number of distinctive benefits are introduced and the first one of them is the ability to exchange electricity across borders. Damsgaard and Green (2005) identify three theoretical aspects of multinational trade of electricity that help to illustrate why the creation of a common electricity market is expected to increase trade across borders and spur efficiency. The first aspect of multinational electricity trade is described as simple electricity trade. The authors conclude that if producers in Sweden offer less expensive electricity compared to producers in Norway, and if consumers are willing to pay this offered price, Sweden will export electricity to Norway. The second aspect of trade is related to transmission flows. If Denmark wants to export electricity to Finland, the majority of the electricity has to be transported through Sweden. Even though Denmark might have direct connection to Finland parts of the power will have to be transported via Swedish transmission lines, hence existing infrastructure will be utilized even more and incentives for investments will increase. The third aspect is related to trade between different peak and off-peak

hours. At certain time periods during the day, Swedish producers will have lower costs than, for example, Danish producers, depending on daily patterns, weather conditions and power plants. During these hours Swedish producers will export power to Denmark. Likewise, Sweden will import power when the costs are lower in Denmark.

In reality, trade flows are very complex and it is rather unlikely that Damsgaard and Greens three aspects can be kept apart in practice. Yet the divisions as such are less important, what is important in the context of this study is that multinational electricity market integration is expected to increase trade across borders, which in turn implies a more efficient use of energy sources.

3.3 Security of supply

The second distinctive benefit of electricity market integration is the increase of security. Prior to the multinational Nordic market, each country and domestic company had to meet the demand for electricity using its own capacity and at the same time, withhold an appropriate amount of reserve capacity to ensure security of supply. With a common market for electricity, the companies do not have to hold the same, high, level of reserve capacity. Instead, lower levels of spare capacity are required and the generation capacity can be utilized even more. The fact that a lower amount of generation reserve is required to maintain a given level of supply reliability can be considered as a second economic benefit of multinational electricity market integration. (Damsgaard and Green, 2005)

3.4 Market concentration and market power

The third distinctive benefit of electricity market integration is related to the competitive environment of the electricity market or more specifically, market power. Market power can be defined in a variety of ways, however a common assertion is that market power refers to the ability of a firm (or a group of firms) to raise and maintain price above the level that would prevail under competition (OECD, 2002). In the absence of market power, market price will equal marginal cost under efficient production and perfect competition.

As previously mentioned, the Nordic electricity markets has historically been dominated by very large network industries acting as monopolists in their own local area. However, when the Nord Pool power exchange was established the functioning of the electric power market changed; the participating countries' electric power generators had to compete with generators from the whole Nord Pool area and as the market for electricity expanded, the large power generators in the individual countries got smaller market shares on the common market. An example of this can be seen in Sweden, where the four largest electric power generators covered 88 percent of the domestic market in 2004, while in the Nord Pool area they only covered 48 percent of the total market. (Lundgren, 2012:7) This indicates that larger electric power markets improve the conditions for the market to function effectively.

In line with this, Cabral (2000) argues that a lower degree of concentration, i.e. higher number of companies on the market, indicates less ability to exercise market power and diminished possibilities to raise prices. Cabral also finds support for this negative relationship in his econometric calculations. Further support for a negative relationship between market concentration and prices comes from eg. Andersson and Bergman (1995), Amundsen et al. (1998) and Johnsen et al. (1999), who all find that lower levels of market concentration is related to competitive behaviour and lower prices on the electricity market. Amundsen et al. (1998) for example study the impact of market power by simulating electricity price formation in Sweden and Norway under various assumptions about electricity trade and competitive environment. The authors compare the effect of increased competition both under autarky and free trade and find that the free-trade price is significantly lower than the autarky prices. Especially if the countries have a high degree of monopolistic pricing pre integration, as have been the case in the Nordic countries.

Still, concerns have been raised about the Nordic power market's actual performance and the risk of large power companies exploiting their market power. In 2006 for example, the Committee on Industry and Trade in the Swedish Parliament held a public inquiry into the electric market - partly motivated by the recent years' sharp increase in electricity prices. In light of the public dissent about the performance of the Nordic electricity markets, Fridolfsson and Tangerås (2009) conducted a survey over empirical research assessing market power on Nord Pool. Notably, the

authors conclude that there is no evidence from previous literature of any systematic exploitation of market power on the Nordic power market.

In a more recent study from 2011, Bask, Lundgren and Rudholm examine more specifically how the reform of the Nordic electricity markets has affected the competition in the electric supply market, Nord Pool. The results show that the electric power generators initially had a small, but statistically significant, degree of market power. However, studying the effect of market integration, the authors show that the degree of market power has been reduced and finally vanished as the market expanded and more countries joined the collaboration.

3.5 Electricity generation structure

Electricity market integration is also expected to affect the generation mixture of the region and consequently the electricity flow between the participating countries, and ultimately, the price level. As previously mentioned, electricity price is heavily based on the marginal costs of production and according to Pikk and Viiding (2013) producers with the lowest short-term marginal costs are owners of wind turbines and hydro plants. Low levels of hydro generation and high levels of relatively more expensive power sources (e.g. fossil fuels) imply that the marginal unit more often will be the more expensive power. This in turn will result in higher production cost and higher electricity prices. In the same manner production cost, and hence also price, will fall with more hydro generation on the market.

Put differently, this means that the Nordic power price is highly dependent on the generation structure of the region. Lundgren, Hellström and Rudholm (2008) conclude that the electricity production structure differs substantially between the Nordic countries. For example, the Lundgren et al. highlight that hydro accounted for 99 percent of the Norwegian power generation in 2005 while in Sweden the same year, hydro only accounted for 45 percent of the power generation. The remaining part was produced by nuclear power (45 percent) and other thermal power sources. According to the authors, the Finnish generation structure is similar to the Swedish but with more thermal power and less hydro. Against this background, the authors argue that it is reasonable to assume that electricity prices will increase due to Nordic electricity market integration, as a consequence of more expensive power sources being the marginal source of

electricity. On the other hand, Pikk and Viiding (2013) argue that the majority of new investments in generation supply are made with significant help from government support schemes in renewable production capacities, which have very low marginal costs. Moreover, since the sale price is the same for all producers on the Nord Pool Spot power exchange, the economically most efficient production units will earn the most, and the units with the highest bidding price will earn just enough to cover their short run marginal costs. As a consequence, rational actors in terms of profit-maximising firms may consider the fact that it may be more profitable to use hydropower, hence the share of more expensive power sources might also decrease.

3.6 Electricity price dynamics

As previously mentioned, the fundamental idea behind a well functioning Nordic power market is that price is set according to the marginal cost of electricity production. Friedman (2011) however argues that this is almost never the case. Referring to United States electricity markets Friedman instead claims that the electricity prices are set at the average cost. Yet studies of the Nordic power exchange show another reality. Opposite to what Friedman finds, Bask et al. (2011) and Nylund (2013) find that the Nord Pool Spot price closely follows the marginal cost of energy production.

When it comes to studies on price effects of multinational electricity market integration the existing literature is rather scarce. However, there are a few exceptions. Bask and Widerberg (2008) have published an article in which the effect of multinational integration on electricity price dynamics is analysed. In the article, the authors conclude that a larger electricity market seems to lower the probability of sudden price jumps and that the market is less sensitive to shocks after the integration process than it was before. This conclusion is strengthened by Lundgren et al. (2008) who also finds that a multinational electricity market appears to handle external shocks to supply and demand more efficient than a separate national market. More recently Brännlund, Karimu and Söderholm (2012) published a report analysing the price effects of the deregulation in the Nordic countries. The article is based on econometric modelling and in line with previous researchers, the authors conclude that the Nordic market seems to function as an effective market is supposed to. However, neither of these articles nor any other previous

papers evaluate the effects of multinational electricity market integration on the actual price level in the Nordic power market.

All in all it can be concluded that a majority of experts and analysts believe that the creation of a common Nordic power exchange has been fairly successful when it comes to creating a competitive and efficient market. Yet the picture is not entirely rosy. There has for example been critique towards the widespread belief among regulators and policy analysts that deregulation and multinational market integration will yield lower electricity prices. One example of this can be seen in Duckworth, Rudkevich and Rosens (1998) article, where the deregulated market for electricity in Pennsylvania, USA is studied. Duckworth et al. claim that there are market aspects, especially in industries with relatively small number of firms that could offset the benefits of increased market competition. In the article, the authors compare the observed electricity prices to the “perfectly competitive” electricity prices that would occur from a Nash Equilibrium-based bidding. The results show that, as theory would predict, the spot price of electricity decrease as the number of generating firms bidding on the exchange market increase. However, even with a relatively low market concentration (i.e. high number of firms), market prices are proved to be significantly higher than the “perfectly competitive” prices. The results by Duckworth et al., suggests that more than 30 firms of equal size are needed to ensure competitive pricing on the electricity spot market.

3.7 Research gaps

Surveying the previous research analysing electricity markets it can be concluded that a fairly extensive part of the literature focus on the competitive part of the market. There are also some literature focusing on electricity price dynamics but studies on price dynamics in the context of multinational electricity market integration remain are very few. Previous literature, e.g. Cabral (2000), Damsgaard and Green (2005) and Lundgren (2012) find that larger power markets improve the conditions for the market to function effectively, but the price effects of these perceived benefits are not always clear and would benefit from further research.

Early studies such as e.g. Andersson and Bergman (1995) and Johnsen et al. (1999) also indicate that electricity spot markets are sensitive to market power and extra susceptible to strategic

behaviour. Add to this the fact that market power is sensitive to market expansion and integration, as highlighted by Bask et al. (2011), and it becomes evident that there are good reasons to perform studies of the Nord Pool Spot market and to understand electricity price formation in competitive multinational power markets. Also, with the new market setup determining prices at a common power exchange, there are new ways of exploring price formation. Almost 20 years have passed since the first multinational power exchange was created in 1996 and the time is thus ready for an evaluation of the outcome of the Nordic power exchange.

4. Aim and research question

The last decade has seen the introduction of several regulatory measures on the Nordic electricity markets, most notably the first multinational power exchange has been created. These measures are expected to have changed the price mechanisms of electricity. The overall aim of this thesis is to analyse the Nordic multinational electricity market integration and evaluate whether (and to what extent) it has affected the electricity price level at the Nordic power exchange. The following research question is identified:

How does multinational electricity market integration affect electricity prices at the Nordic power exchange?

5. Theoretical model

5.1 Two tracks leading towards an electricity price

Based on the previous research section a theoretical model that explains electricity price can be constructed. The ability to exchange electricity between countries in a large region has proven to have implications of both technical and economic character. This includes higher utilisation of installed capacity, a larger market with more participants that can increase competition and reduce market power, and improved security of supply (Nylund 2013:4). In the theoretical model, these factors are described as drivers behind the level of electricity price and two parallel tracks are considered.

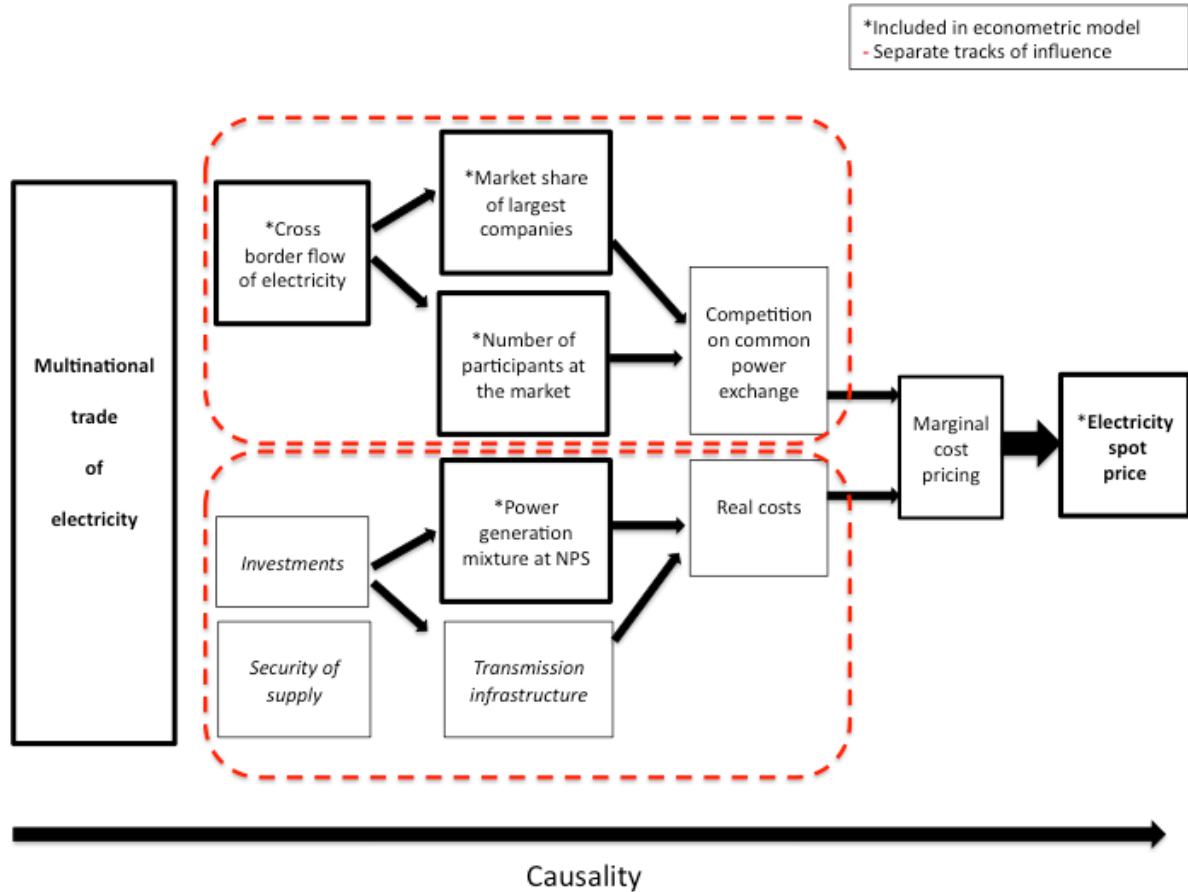
The first track of the theoretical model is related to the Nord Pools Spot's market structure. As was previously described in the research section, larger electric power markets helps to improve the conditions for the market to function effectively. Larger electricity markets may not only increase competition but it may also reduce market power, as pointed out by Lundgren in his article from 2012. Add to this the fact that several researchers find support for a negative relationship between market concentration and electricity prices and it becomes evident that a link is to be expected between multinational electricity market integration and electricity prices at the Nordic power exchange. Based on the findings in the previous research section it is reasonable to assume that as the common market for electricity grows, i.e. as the traded volumes on the Nord Pool spot increase, electricity flow across border intensifies and the market structure of Nord Pool spot change. More companies enter the common market for electricity and this leads to higher levels of competition and lower levels of market power. Ultimately, this change in market structure due to the enlargement and multinational integration of the electricity markets is expected to lower the spot price at the Nordic power exchange.

The second track of the theoretical model is related to the cost of producing electricity. Previous research show that electricity producers' pricing methods are affected by multiple factors such as variable costs of production, investments and fixed costs and weather. However, the most affecting factor is the generation type, and the marginal cost related to the specific generation source. Electricity price is heavily based on the marginal costs of production and as previously discussed, hydro and wind are considered the cheapest power sources. As for the Nordic countries, Lundgren et al. (2008) conclude that the electricity production structure differs substantially between the countries. Market integration and hence new participants entering the Nord Pool exchange is therefore expected to change the generation structure of the region and consequently also the price level.

In summary, according to the theoretical model, the spot price of electricity is assumed to be determined as follows. First, the long-run equilibrium price of electricity reflects the marginal cost of producing that electricity. Second, the marginal cost and the associated marginal bids are determined by changes in market structure and supply structure. In the empirical part of this thesis, I would therefore expect that market integration has the following effects on the price.

Partly, market integration on the Nord Pool has changed the supply structure towards more expensive thermal power. The restructuring of the market thus implies that there is an increased probability of more expensive power sources being the marginal source of electricity. This in turn, would lead to higher prices as the electricity market becomes more integrated. However, as the market becomes more integrated, the composition of the market change and the companies are less likely to exploit market power (i.e. to maintain prices that are higher than the lowest possible marginal cost of production). In addition to this, multinational electricity market integration is expected to bring additional economic benefits in terms of security of supply, increased investments and efficient use of the transmission infrastructure. The aggregated effect of integration on prices is therefore expected to be negative, i.e. as market becomes more integrated prices are expected to decrease.

Figure 5.1 Graphic presentation of theoretical model.



5.2 Delimitations of the theoretical model

To construct a comprehensive model of how the price of electricity is set is a huge task and outside the scope of a study this size. The model constructed in this thesis focuses on the effects of electricity market integration and factors closely linked to market structure and the supply side of electricity, such as generation composition, market share of main actors and companies. Moreover, it is an analysis of the multinational spot price. Domestic policy areas that are likely to affect the domestic electricity price, such as tax, technical standards on transmission infrastructure and bottlenecks, are therefore not taken into account. Nor are entire policy areas such as environmental standards and emission allowances that may affect the production cost for electricity generation based on fossil fuel.

5.3 Hypothesis derived from the theoretical model

According to the theoretical model, electricity prices should be lower if the electricity markets have been liberalised and integrated, compared to years where this is not the case. In other words, multinational electricity market integration is expected to have a negative effect on prices. This means that the electricity price is expected to be low during the years when the common market trading is high, the electricity flow across border is high, market shares of the main companies are low, market concentration is low and change in generation structure high.

6. Method and operationalisation

6.1 Delimitations

The graphic presentation of the theoretical model identifies a number of explanatory factors and causalities, although to examine them all would constitute a huge task. In order to keep this analysis within a reasonable size while at the same time covering the central parts of the theoretical model, a number of delimitations will be made.

Due to the fact that the Nordic countries effort to create a multinational electricity market is the main focus of this thesis, most attention will be given to factors within this field. The size of the common power exchange and the flow of electricity across borders stand out as vital factors to examine. As theorized it is also important to take into account the characteristics of the market in terms of number of companies and market shares. Hence these variables are included in the empirical study. Previous research has also shown that generation structure plays an important role for the price level of electricity and due to the relative ease in obtaining data within this area this factor will also be included in the empirical study.

The rest of the factors in the theoretical model (security of supply, transmission infrastructure, investments) will not be included in the empirical part of this study. However, it is important to keep these aspects in mind when discussing the results and future research.

6.2 Data sources

The vast majority of the data used in the empirical study have been provided by three main data sources: Nord Pool, European Network of Transmission System Operators for Electricity (ENTSO-E) and the Nordic Energy Regulators (NordREG). The data cover the time period week 1, 1996 to week 52, 2014. The time span stretches from 1996 to 2014 since the Nord Pool power exchange was created in 1996, hence data on Nord Pool price and other market indicators are only available from 1996 and onwards. All in all, the sample consists of 988 weekly observations.

Nord Pool compiles data in its FTP database for various types of indicators related to the physical Elspot market. The FTP database constitutes the key data source for this thesis with regards to price information and market indicators such as traded volume and number of participants. Besides Nord Pool, data on market indicators have been obtained from NordREG which serves as a second important data source for this thesis. NordREG compiles reports annually that describes the state of the Nordic electricity market. These reports provide useful information about the Nordic power exchange and serve as a complement to Nord Pool's FTP database, especially when it comes to market size indicators in terms of total volume as share of electricity consumption.

Apart from Nord Pool and NordREG, the European Network of Transmission System Operators for Electricity constitutes the third main statistical source of this thesis. The ENTSO-E statistical database encompasses a range of historical data sets regarding power systems and the data of interest for this study is related to electricity flow statistics. However, the database only contains data for the years 2010-2014 since the organisation was established 2009. Data for the years 2009 and before have been compiled by ENTSO-E's predecessors and are only available in ENTSO-E's published reports. The publications of interest for this study relates to the section called "Nordel".

Additional data sources used in this study is Sweden Energy AB and Eurostat. Eurostat provide data on GDP and Sweden Energy AB compiles reports annually that describe the Swedish electricity market. Especially its latest report "The electricity year 2014" provide useful information about market shares of main companies at the Nordic electricity market. The drawback with the Sweden Energy data is that it only exists for the period 2002-2014. But to the author's knowledge, the data cannot be obtained elsewhere and the variable is considered too

important to be left out of the statistical analysis. Data on market shares is essential for assessing market competition and it provides a useful complement to the other market indicator measuring number of participants at the market. This means that the study will examine a maximum of twelve years when the market share variable is included in the statistical model. Although a longer time span would be ideal, the period represents a rather extensive amount of years and a time where multinational electricity market integration has increased, and the effects thereof, should be clear.

Also note that the data compiled by ENTSO-E, NordREG and Swedish Energy AB is annual and not weekly. For a complete list of explanatory variables and their missing values see Appendix I table 1. The descriptive statistics (mean, max, min, dev, etc) of the data are reported in the same Appendix, table 1.

6.3 How to measure electricity price

The price of electricity can be measured in a variety of ways. First off, it is important to underline that price for industrial and domestic consumers differ due to extra cost of distributional networks for domestic consumers. On top of this, national taxes are added. The aim of this thesis is to study the Nordic power exchange and *not* the individual electricity markets. Hence the price for industrial consumers is more important for this study than the domestic area prices. Analysing the domestic area prices would introduce too much “noise” in the analysis in terms of transmission constraints and domestic policy differences. Using the industrial spot price allows for a more in-depth analysis of market integration effects and it enables a study that more clearly isolate the factors influencing the market price.

The system spot price is measured in Euro per megawatt hour and data is obtained from Nord Pool Spot. The price serie is constructed using weekly prices and in the theoretical model the spot price for electricity without any taxes or transmission constraints will be used as dependent price variable.

Before 2000, the spot price was referred to in Norwegian crowns. The weekly prices 1996-2000 have therefore been converted to Euro using the monthly exchange rate reported by Antweiler (2015).

6.4 How to measure competition

In a perfectly competitive market, there will be a large number of sellers. According to economic theory, the number of sellers could on the one hand be an indicator of economies of scale and on the other hand an indicator of price taking behaviour and utilization of market power in general. Nord Pool reports data on number of participants on the Nord Pool Spot market and this is one way to measure market concentration. However, it is flawed in the sense that it cannot distinguish between situations where a few big companies holds almost the entire market compared to situations where numerous smaller companies share the market. To measure this it is important to consider the cumulative market share of the main companies.

To measure the cumulative market share of the main companies an arbitrary boundary of what can be considered a main company must be set. From previous studies it is clear that the Nordic market is dominated by four power generation companies; Vattenfall, Fortum, E.ON and Statkraft. (Hellmer and Wårell, 2009:3237; Fridolfsson and Tangerås, 2009:3682) These four companies control a majority of the electricity production on the national markets and will constitute the “main companies” of this thesis.

The market shares of the four main companies will be calculated as the company's production share of the *total* electricity production in the Nordic countries. The reason why the *total* electricity production is the basis for the calculation, and not only the electricity traded at Nord Pool Spot, is because of data limitations. Nord Pool does not provide data on traded volumes by producer, nor does the national agencies such as e.g. Swedish Energy AB. The only data available, to the authors knowledge, is the company's production in relation to the total electricity production in the Nordic countries. This means that the indicator will *not* reflect the development on the Nord Pool Spot market, but the development in the Nordic countries. The measurement is still considered adequate for the purpose of this study since it reflects the company's market shares on the *multinational* Nordic market. Another argument for this measurement is that without

a well-functioning wholesale market the development of a competitive exchange market is not feasible.

A high number of participants on the Nord Pool Spot market, and low score of the cumulative market share of main companies on the Nordic market would, according to the theoretical model, indicate a competitive market and lower prices. Hence competition will be operationalised as two separate variables, one measuring the number of participants on the market, and one measuring the cumulative market share of the four largest companies on the market. The variable containing information about the number of participants is expected to have a negative relationship with price, i.e. when the number of companies increases, competition increases and prices fall. The variable on cumulative market share is expected to have a positive relationship with price, i.e. as the main companies increase their market shares competition is reduced and prices increase.

6.5 How to measure multinational integration

In this thesis, market integration is understood as a continuous event occurring over time. In line with this definition, the integration effect will be measured through a number of continuous variables. An alternative method would be to use dummy variables for integration, as Lundgren et al. do in their article from 2008. However, a dummy approach implies that market integration is a single event occurring at a certain time(s) in history. It would not enable an analysis of the continuous effect of market integration but rather represent a one-time change in prices. The degree of market integration will therefore be measured through a number of market indicators representing the level of integration.

The first multinational market integration variable is the total volume traded at the Nord Pool Spot market. The amount of electricity traded on the Nord Pool power exchange is measured in gigawatt-hours per week and data is obtained from Nord Pool's FTP server. The variable helps to illustrate the size of the market and its activity. However, the measurement is flawed in the sense that it does not say anything about the relative size of the market. A large amount of traded volumes does not necessarily mean that the countries are integrated. To account for this, a second variable will be included which measures the volumes in the spot market as share of the total Nordic electricity consumption. Data on traded volumes as share of total consumption can be

obtained from the “Nordic energy market reports” published annually by NordREG. These reports are compiled to give the reader an overview of the development of the Nordic energy market and in the associated statistical package there is a list of relevant indicators for the electricity market.

Because integration aims to increase trade across borders measures of electricity flow across borders can be used as a third variable and indicator of multinational market integration. The measurement also serves as a complement to the previous variables since a growing market for common trade not necessarily implies a more integrated market. One must also consider the flow of electricity across borders. The European Network of Transmission System Operators for Electricity (ENTSO-E) encompasses a range of historical data sets within the field of power systems, among others there is a data set measuring the annual flow of electricity between the Nordic countries. The data is categorised according to the five boundaries of Scandinavia, measuring the import and export of electricity between Sweden and Finland (1), Sweden and Denmark (2), Sweden and Norway (3), Denmark and Norway (4) and Norway and Finland (5). An average exchange rate per border is then calculated by summarizing the yearly exchange rates and dividing by five. The average exchange rate per border is measured in gigawatt-hours per year.

In conclusion, multinational market integration is operationalised as three different variables. The first two variables are rather size oriented. Both the variables are expected to have a negative relationship with the price of electricity, i.e. as the total traded volume increases and a larger share of the electricity consumption goes through the common spot market, the multinational market grows and efficiency gains make the price decrease. As for the third variable for multinational market integration, electricity flows across borders, the variable is expected to have a negative relationship with the price of electricity, meaning that as electricity flow across borders increase price decrease.

Only two of the three multinational market integration variables will be included in the statistical model. The variable “total traded volume” and the variable “volume as share of total electricity consumption” both measure the same thing but in different ways and due to the high risk of multicollinearity only “total traded volume” will be included in the statistical model.

6.6 How to measure generation structure

As shown in the section of previous research, generation type and supply structure play a vital role in electricity price formation and multinational electricity market integration. Data on generation capacity by power source in the Nordic countries can be obtained from ENTSO-E and NordREG's annual reports. Data is reported in megawatt, the 31st of December each year.

Based on the data from ENTSO-E and NordREG, generation structure is then calculated and operationalised as *one* variable measuring the *total change* in generation structure at the Nordic power market. The reason for calculating one variable measuring the total change at the market and not several different variables for each generation source is because this study mainly focuses on multinational electricity market integration and price. The aim is not to thoroughly analyse how integration affect the generation structure in the region and in light of this, it is considered adequate to measure the general change at the market.

The variable is calculated in two steps. First, the annual share of each power source is calculated, i.e. the share of capacity that comes from hydropower, the share of capacity that comes from nuclear power, the share of capacity that comes from other thermal power and the share of capacity that comes from other renewable power. Each variable is calculated as the annual share of the total generation capacity of the Nord Pool participating countries. Hence data for 1996 and 1997 illustrates the generation structure of Sweden and Norway. Finland joins the Nord Pool market in 1998 and Denmark in 2000. Second, in order to create *one* variable measuring the change in generation structure at the common power market, the variables are merged into one variable measuring the total change in generation structure from one year to the following year. The variable is calculated as the sum of the percentage change between the different power sources each year. E.g. if the share of hydro generation increase by one percent from year one to year two, and the share of nuclear generation decrease by one percent during the same time, the total change in generation structure from year one to year two equals one percent. Hence if the variable increases, it indicates that the market structure of the common power market change. However, it does not say anything about which power sources that increase or decrease.

The generation structure variable is expected to have a negative relationship with price, assuming that companies are rational actors striving to maximize their profits by lowering their production costs. As integration increase, the generation structure of the common power market change towards less expensive power (i.e. the variable “change in generation structure” increase) and prices decrease.

6.7 Control variables

Because this thesis does not create a comprehensive model on electricity pricing it is important to control for other factors that might affect the spot price at the Nordic power exchange. There are a few factors that are considered important to the spot price of electricity.

It has been concluded that generation type is important for the marginal cost of producing electricity and hence also for electricity pricing. Closely related to this discussion is the question about hydro reservoir levels. A low level in hydro reservoirs will mean that producers use more expensive sources which will result in a higher production cost and potentially also higher electricity prices. In the same manner production cost will fall with more water in the reservoirs. (Nord Pool Spot, 2016) Hence the Nordic power price is also dependent on both rainfall levels and access to nuclear power and the price of other sources. The aim of this thesis is not to determine all potential factors that could affect electricity price but rather to show the potential effects of market integration on electricity price. However, since rainfall levels and fuel price such as oil have been highlighted as important factors behind electricity price formation I will control for these factors in the econometric model.

Temperature might be another reason behind rising electricity prices. As temperature decreases, the demand for electricity increases and the electricity price is therefore likely to increase. The temperature variable is aggregated and measures the average mean in Celsius for Sweden, Norway, Finland and Denmark, 1996-2013. For reasons of time, data has been obtained from the appendix of Romarker and Wennerström (2015). In their appendix, the authors have calculated an aggregated yearly mean for the Nordic countries based on data from the Swedish Meteorological and Hydrological Institute (SMHI), the Norwegian Meteorological Institute, the Finnish Meteorological Institute (FMI) and the Danish Meteorological Institute.

GDP per capita will be used to control for the level of economic development. The variable is obtained from Eurostat and measures the real average value of GDP per capita for Sweden, Norway, Finland and Denmark in EUR per inhabitant.

6.8 Statistical method

This thesis uses a quantitative approach with times series data from 1996 to 2014. The method used is an Ordinary Least Squares (OLS) linear regression. This method was chosen because it is a generally accepted and straightforward method of making statistical inference.

When analysing time series data, there are some statistical problems that need to be dealt with. One problem stemming from the time dimension of the data is the risk for *autocorrelation*. Put simply, autocorrelation means that the observations are correlated across time, that the error term is correlated with error terms from previous years in the time series. This in turn might cause bias results and an outcome where our results look more statistical significant than they really are. A Durbin Watson test helps to identify any serial correlation and the results indicate that this is a problem since the null hypothesis of no autocorrelation in the data is rejected. In an effort to solve this problem, a lagged dependent variable will be used in the model.

Another problem stemming from the time dimension is the risk of *non-stationary data*, i.e. that there is a common trend in the data that may mislead the results. A high correlation in the data could be the result of a similar trend among the indicators, moving upwards or downwards at the same time. To make sure that the time series are stationary a Dickey Fuller test is conducted. The results confirm that all variables appear to be stationary. Nevertheless, both the price variable and the variable for traded volumes contain seasonal patterns, in the short run (weekly patterns) as well as the long run (intra yearly patterns). In order to capture the short run seasonality, weekly prices are used. Seasonality within the years is captured by including weather related variables in the regression model. Both the inflow of water to the reservoirs in terms of rainfall and the average temperature show seasonal patterns. Hence, these variables should be useful in order to capture seasonality in the electricity price.

A third aspect that is important to consider in regression analysis is the potential co variation or correlation between the independent variables, also known as *multicollinearity*. If there is a problem of multicollinearity in the model, the standard errors of the variables are affected and subsequently also the statistical inference (Wooldridge, 2013: 83-85). However, the average VIF-value of the model in this study is substantially lower than 10 and multicollinearity does not appear to be a problem. Although one of the variables has an individual VIF-value larger than 11 and two variables are close to the limit with VIF-values between 6 and 7. This is a cause for concern and the individual effect of these variables therefore have to be treated with caution.¹

Finally, to account for any heteroscedasticity, i.e. when the error terms of the variables are not normally distributed, a robust method will be used.² This method is commonly used and helps to correct the modelling errors and contribute to valid statistical tests of significance.

As always with quantitative methods the causal direction can be questioned. However, since the model that is being tested is backed up by theory, reasonable arguments on the causal directions can be made.

6.9 Statistical hypothesis and equation

In order to answer the research question a statistical hypothesis can be derived. The hypothesis reads as follows:

The multinational integration variables; cross border flow and total traded volume at Nord Pool Spot are expected to have negative relationships with price levels, i.e. coefficients are significant and negative. The cumulative market share of the four main companies is expected to have a positive relationship with price while the number of companies is expected to have a negative relationship with price levels. The change in generation is expected to have a negative relationship with price level.

¹ See Appendix I table 2 for VIF values

² Robust option in Stata

As for the control variables, temperature and rainfalls are expected to have negative relationships with price levels. GDP per capita is expected to have a positive relationship with price levels.

In mathematical terms, this is the econometric model to be estimated:

$$\begin{aligned} \ln(\text{spot price})_t = & \beta_0 - \beta_1 \ln(\text{traded volumes})_t - \beta_2 \ln(\text{cross border flow})_t \\ & - \beta_3 \text{number of partipants}_t + \beta_4 \text{cumulative market share}_t - \beta_5 \text{change in generation}_t \\ & - \beta_6 \text{temperature}_t - \beta_7 \text{rain levels}_t + \beta_8 \text{oil price}_{t-51} + \beta_9 \ln(\text{GDP/capita})_t + e_t \end{aligned}$$

β is the coefficient, e is the error term and t is the time period specified as week per year. The variables spot price, cross border flow and traded volumes are expressed in logarithmic form in order make them unit-independent. This offers a more straightforward interpretation and the possibility to interpret the relationship as elasticity. If for example, the cumulative market share of main entities increases by one percentage point the potential change in spot price is interpreted in percent.

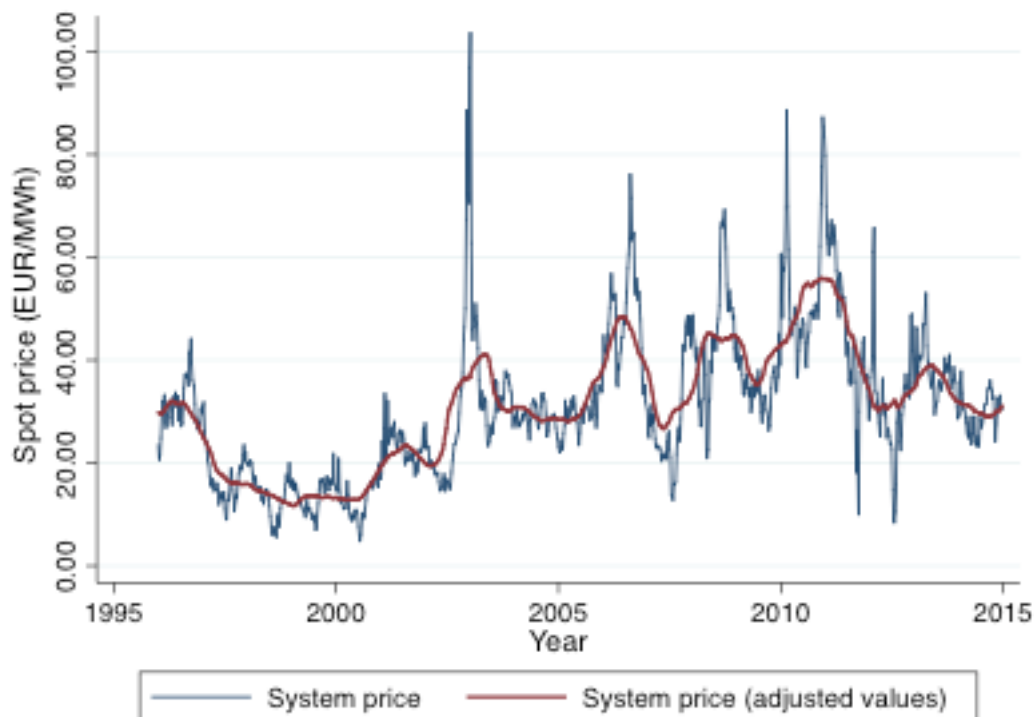
7. Results

7.1 Presentation of variables – trend and observations

The following section will present the characteristics of the dependent variable, electricity spot price and the key independent variables; traded volumes at Nord Pool Spot, cross border electricity flow, number of participants on the Nord Pool Spot market and the cumulative market share of the four main companies on the market. A frequency distribution of the dependent variable is presented in Appendix I.

Figure 7.1 The Nord Pool Spot price, 1996-2014.

Euro per megawatt-hour



Comment: The figure illustrates how the spot price has developed at the Nord Pool Spot market, weekly 1996-2014. The Y-axis measures EUR per MWh and the X-axis represents the time dimension measured in years.

Source: Nord Pool FTP server

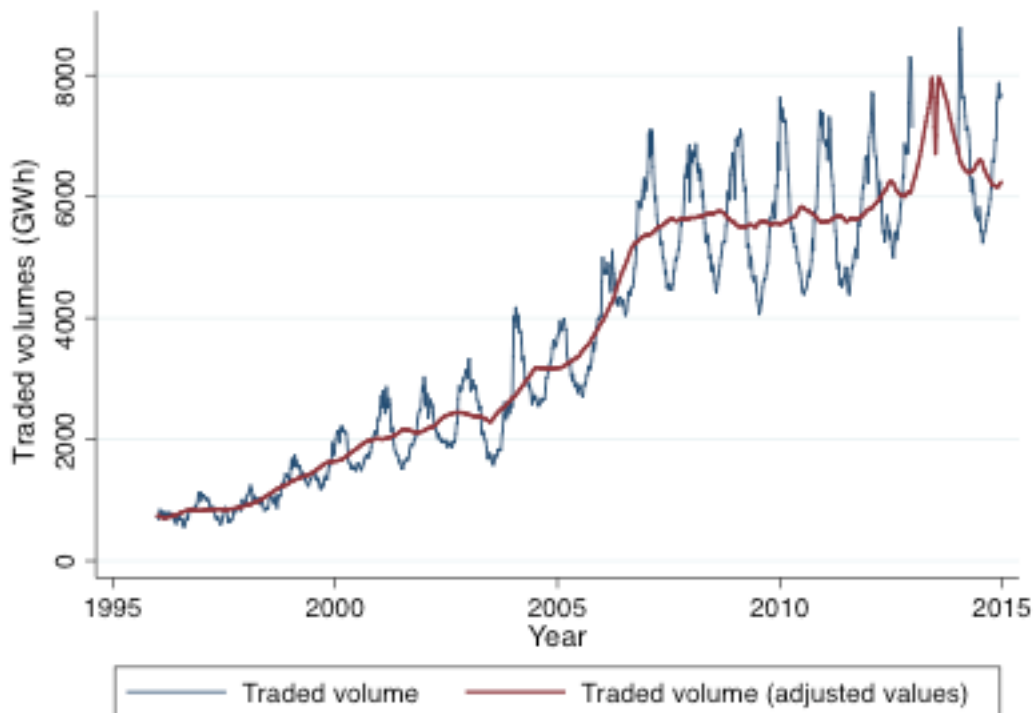
Figure 7.1 above shows the fluctuations of the spot price during the time period of this study. The blue line represents the weekly spot price and the red line represents the seasonal adjusted spot price in terms of the moving average of the weekly spot price. As suspected, the blue line

fluctuates a lot over time and this strengthens the suspicion that the spot price is determined by seasonal factors such as temperature and rain levels. Hence, this is controlled for in the statistical model.

The figure also shows that there is a clear price decrease during the early years of the Nord Pool Spot market, from 1996 to approximately 2000, which is interesting considering the fact that the period coincides with the integration period of the Nordic electricity markets. Sweden joined Nord Pool in 1996, Finland in 1998 and Denmark 2000. Hence the early price decrease might be a sign of integration effects. However in the long run, 1996-2014, there is no clear downward price trend. The graph shows rather the opposite, since 2000 there has been a price increase up until 2011 when there is a slight price decrease again. In 2015 the price level is basically at the same level as in 1996.

Figure 7.2 Traded volumes at Nord Pool Spot market, 1996-2014.

Gigawatt-hours

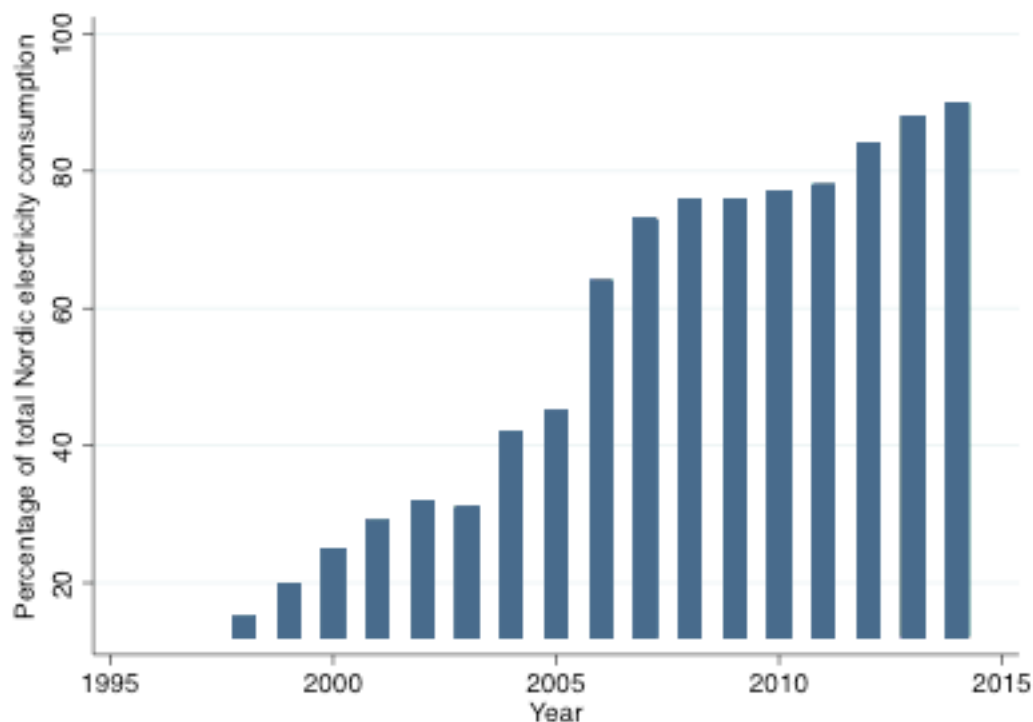


Comment: The figure illustrates how the traded volume has developed at the Nord Pool Spot market, weekly 1996-2014. The Y-axis measures GWh and the X-axis represents the time dimension measured in years.

Source: Nord Pool FTP server

Figure 7.3 Traded volumes as share of electricity consumption, 1997-2014.

Share (%) of total Nordic electricity consumption



Comment: The figure illustrates traded volumes at Nord Pool Spot as share (%) of the total Nordic electricity consumption per year, 1997-2014. The Y-axis measures percent and the X-axis represents the time dimension measured in years. Source: NordREG.

Figure 7.2 shows the amount of electricity traded on Nord Pool power exchange during the period 1996-2014 and figure 7.3 shows the percentage of electricity as share of total consumption of electricity in the Nordic countries for each year of this thesis. Both figures illustrate an extensive growth of the Nordic power market over time. Figure 7.2 shows that the amount of electricity handled by the Nord Pool Spot has more than tenfold during the time period of this study. Figure 7.3 illustrates this significant growth as percentage of the total electricity consumption in the Nordic countries. In 1996, the Nord Pool Spot market covered approximately 6 percent of the electricity consumed in the Nordic countries. In 2013, the market covered about 90 percent. This indicates that the liquidity of spot market has increased over time. Market liquidity in turn, is essential to the function of wholesale markets, as it allows the formation of competitive prices.

Figure 7.4 Average cross border electricity flows in the Nordic countries, 1996-2014.
Gigawatt-hours

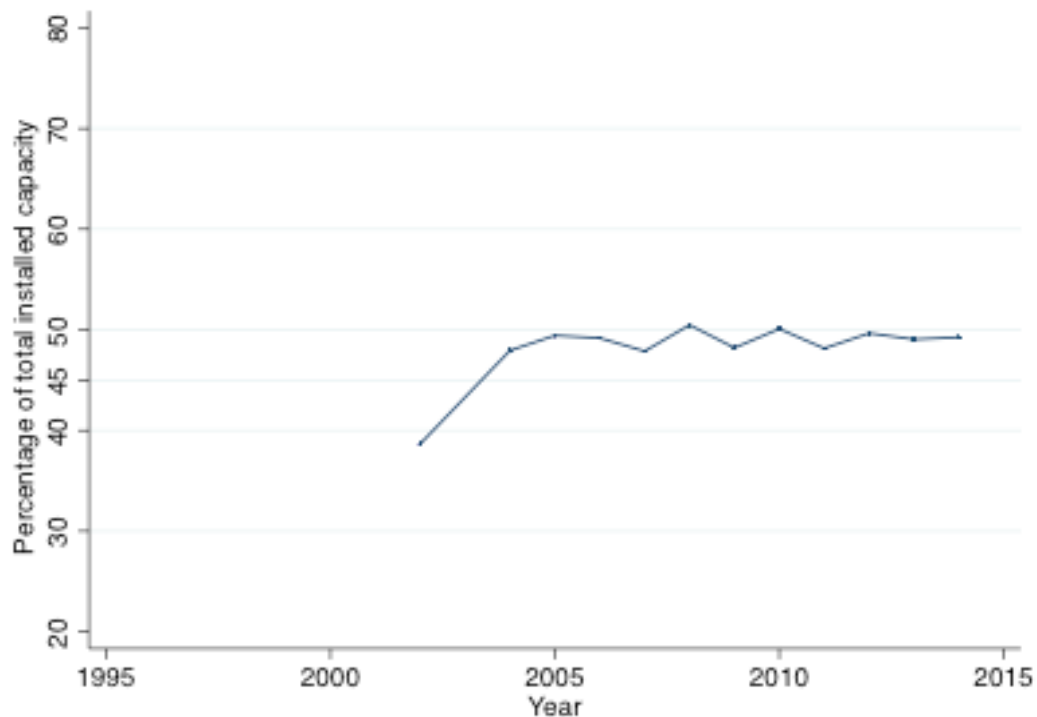


Comment: The figure illustrates the amount of electricity that flows across the five borders of the Nordic countries per year, 1997-2014. A list of country borders can be found in Appendix I, table 3. The Y-axis measures GWh and the X-axis represents the time dimension measured in years. Source: ENTSO-E.

Figure 7.4 shows the average cross border flow of electricity between the Nordic countries 1996 to 2013. The graph fluctuates a bit but confirms that the average flow of electricity across borders has increased over time. As suspected, it seems as if integration coincides with intensified electricity flows across borders. This indicates that the common market for electricity has grown not only in terms of traded volumes but also in terms of exchange between the participating countries.

Figure 7.5 Cumulative market shares of main companies, 2002-2014.

Share (%) of total installed capacity in the Nordic countries



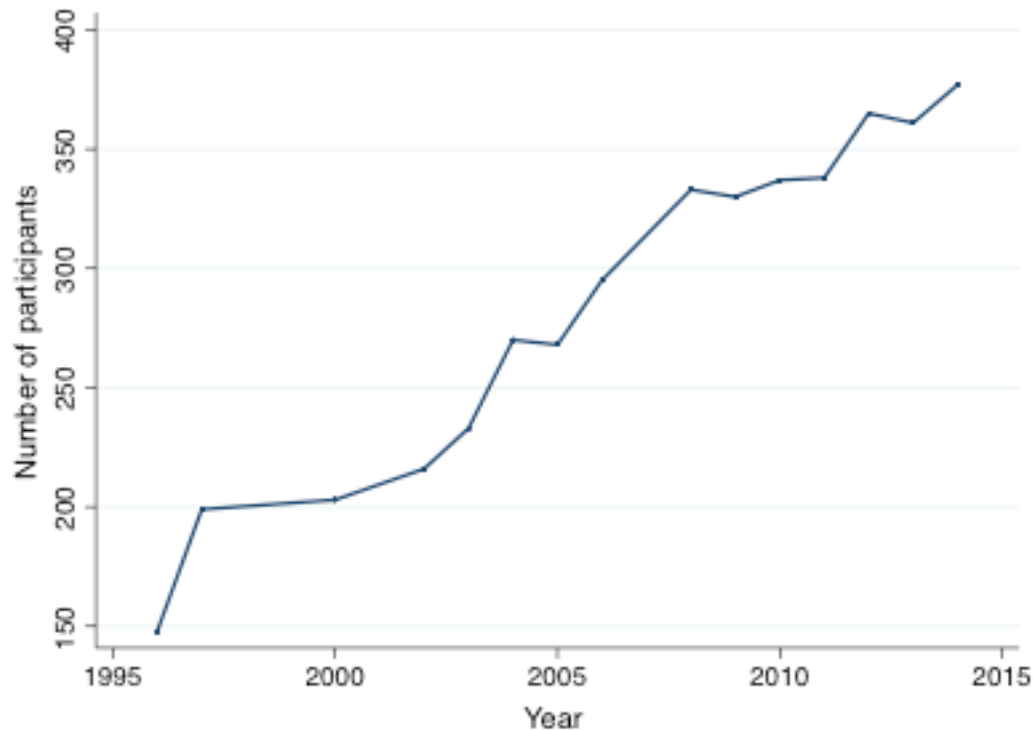
Comment: The figure illustrates the cumulative market share of the four main companies (Vattenfall, Fortum, E.ON and Statkraft) at the Nordic electricity market, 2002-2014. The Y-axis measures the share (%) of total installed capacity in the Nordic countries and the X-axis represent the time dimension measured in years.

Source: Sweden Energy AB (2014)

Figure 7.5 shows the cumulative market share of the five main companies as percentage of total installed capacity in the Nordic countries, 2002-2014. The trend is rather modest but it implies a move towards a slightly more concentrated market where the main companies are growing bigger or at least maintaining their market share. However, before drawing any conclusions one must also consider the number of participants trading on Nord Pool Spot's market. As figure 7.6 shows below, there is an increasing trend and the number of participants has increased substantially over time, from 148 participants in 1996 to 377 participants in 2014. This indicates a market where more companies are active and according to theory, this should have a lowering effect on price since an increasing number of companies are assumed to increase competition.

Figure 7.6 Participants at the Nord Pool Spot market, 1996-2014.

Quantity



Comment: The figure illustrates the number of participants on the Nord Pool Spot market and how it has developed per year, 1996-2014. The Y-axis measures the number of participants and the X-axis represent the time dimension measured in years. Source: Nord Pool FTP server.

7.2 The effect of market integration on electricity price

In an effort to explain the above-presented variances and the underlying drivers of change, the following section will present the regression results and examine the relationship between market integration and price.

Table 7.1 presents the estimated results for the regressions made in the data analysis of equation (1). In this study, the effect of multinational electricity market integration is measured via two separate variables, partly via the traded volume variable from Nord Pool Spot and partly via the electricity flow variable from ENTSO-E. Studying the regression results in table 7.1, a few observations can be mentioned.

First, through all three columns in table 7.1, the coefficient for traded volume is significantly positive. This means that, opposite to what was expected, traded volumes appears to have a positive impact on the spot price. As the power market grow and more electricity is traded at the Nord Pool Spot market, prices rise. The positive relationship between traded volumes and price is rather surprising given that economic theory often argue that increased market integration is expected to lower prices. A potential explanation to the unexpected (positive) sign of the coefficient could be that there are underlying factors mediating the relationship between the variables. One such factor could be import from third countries. Electricity generators at the Nord Pool power market might have had to import electricity from third countries (e.g. Germany, Russia or Poland) during peak load hours or in times of severe supply shocks. Imports from third countries are often associated with higher costs and this could potentially explain why there is a price increase when traded volumes at Nord Pool Spot increase. It is also worth mentioning that the positive relationship between traded volumes and price could be an indicator of insufficient measurement. Just because electricity is traded on a common power market, it does not necessarily mean that the countries are integrated, i.e. that the countries exchange electricity with each other. The results may be an indicator of distribution still being mainly domestic, potentially due to transmission constrains in the cross border grid systems. However, it is important to underline that the coefficient for traded volumes is relatively small, indicating that the effect is rather weak. More specifically, the estimated coefficient of the multivariate regression in column three shows that if traded volumes per week increase by one percentage point, the weekly spot price of electricity will also increase, with 0,2 percent on average.

As for the other multinational integration variable measuring the average electricity flow across borders, the coefficient is more in line with what was expected. At least in column three, which represents the full model. Initially, in the bivariate regression, the explanatory variable shows a significantly positive effect on price meaning that as the average flow of electricity increase between the Nordic countries, prices rise. However, when the full model is run and control variables are added the coefficient becomes significantly negative. Hence it can be concluded that the average flow of electricity across the Nordic borders has a significantly negative effect on prices. As more electricity flow across the Nordic borders, the spot price of electricity decrease.

The estimated results tells us that a one percentage point increase of the average flow of electricity across borders will result in a spot price decrease of 0,8 percent on average.

Using the variables as indicators of multinational electricity market integration the regression results imply rather mixed signals. It can be concluded that size and flow matter for the level of electricity price, although the effects are not entirely as expected. On the one hand, the results indicate that market integration in terms of interconnectivity and electricity flow across borders has a *negative* effect on prices, i.e. as the average flow of electricity increase, prices on electricity decrease. On the other hand and in contrast to what was expected, the results also indicate that market integration in terms of traded volumes has a *positive* effect on prices, i.e. as more electricity is traded on the common market for electricity, prices on electricity increase. This means that the integration variables of this study work in different directions, one variable drives up the electricity spot price and the other one drives down the electricity spot price. The overall effect of electricity market integration on price is therefore precarious to determine. It could be argued that the combined effect is likely to be negative, since the estimated (negative)effect of the second variable, electricity flow, is relatively strong compared to the estimated (positive)effect of the first variable, traded volumes. Though the descriptive statistics of the dependent variable contradicts this argument as it indicates that there has not been any substantial price decrease of the spot price 1996-2014. The descriptive statistics also show that the market has been growing substantially when it comes to traded volumes while the increase in terms of electricity flow across borders have been more modest. This could potentially explain why there is no overall price decrease in the descriptive statistics over time. The market has simply seen a much higher increase in traded volumes than in flow across borders, which evens out the integration effect.

All in all, it can be concluded that the data of this study finds support for the presumed relationship between market integration and electricity prices at the Nordic power exchange. Although it does not find support for any conclusion that multinational electricity market integration necessarily *lowers* the electricity price.

7.3 The effect of market structure on electricity price

Studying the bivariate regression results of table 7.1 it can be concluded that the market structure variables prove to have a small but significantly positive relationship with electricity price. Although when the full model is run and controls are added, the results change and a few things are worth noting.

First, the significance disappears for the market structure variable measuring the cumulative market share of the main entities. The coefficient is still positive, as expected by the model, indicating that as the market share of the four main companies on the Nordic electricity market increase, price rise. Nevertheless, the variable is not significant and the conclusion is therefore that the data do not support any presumed relationship between market shares and electricity price.

The second observation to be made is that the sign of the coefficient measuring the number of participants on the Nord Pool Spot market becomes negative when the full model is run. The effect on price is rather small but the coefficient is significant and the estimated result tells us that for every extra participant on the Nord Pool Spot market, the electricity spot price decrease by 0,002 percent on average. In line with what has been theoretically argued, the coefficient indicates that as more companies establish on the electricity market, prices decrease.

7.4 Generation structure, lagged dependent and control variables

In line with what has been previously argued about the importance of generation type and associated production costs, the bivariate regression results in table 7.1 show that the generation structure variable has a negative effect on price. This means that as the generation structure change on the electricity market, prices decrease. The data used in this study does not show exactly *how* the generation structure has changed, i.e. which power source that has grown/decreased relative the other. Although the results confirm what many researchers such as Lundgren et al. (2008) and Pikk and Viiding (2013) have argued before, that changes in generation structure is a driving force behind the electricity price level. Also, since the sign of the coefficient is negative, it could be argued that the change in generation structure represents a

change towards less expensive power sources being the marginal source of electricity. An interesting observation considering the fact that previous researchers, e.g. Lundgren (2008), argue that there is an increased probability of more expensive thermal power being the marginal source of electricity when that Nordic countries integrate. However, the results turn insignificant when the full model is run and even if the coefficient is still negative the data does not support any conclusion about the explanatory variable and its effect on price.

As suspected the lagged dependent variable has a relatively large effect on the dependent variable, which is quite logical due to the inherent serial correlation that prices tend to have over time. The variable is still significant when lagged oil price is included to the model, indicating that the spot price is determined both by previous electricity prices and by previous years oil prices.

The variables controlling for seasonal differences also show significant bivariate results, indicating a relationship between temperature and electricity price and between rain levels and electricity price. Yet when the full model is run, the significance disappears. The same goes for the BNP variable, which initially proves to have a rather large effect on electricity price. But when the full model is run the significance disappears.

7.5 Full model

As shown in table 7.1, three of the key explanatory variables have statistically significant effect on the spot price when the full model is run in column three.

Both integration variables prove to have significant effects on the electricity spot price and it can be concluded that there is a relationship between market integration, measured as traded volumes and average electricity flow across borders, and the electricity price at Nord Pool Spot. However, the data does not support any conclusion that multinational electricity market integration necessarily lowers the electricity price. Intensified electricity flow across borders appears to be a factor that contributes to a price *decrease*. The variable is expressed in logarithmic form and the estimated coefficient 0.745 tells us that if the average cross borders electricity flow increase with one percentage point, the weekly price will decrease with 0.745 percent on average. The size of the power market on the other hand, measured as traded volumes, appears to be a factor that

contributes to a price *increase*. The coefficient 0.171 tells us that if traded volumes increase with one percentage point, the price will increase with 0.171 percent on average. This is a rather small effect but yet statistically significant and it indicates that as the market grows in terms of traded volumes, the spot price increases. Not the reverse as expected by theory.

In general it can thus be concluded that flow of electricity is an important factor that contributes to the lowering of prices at the Nordic power exchange. Then what about the size of the market? Before drawing any conclusions here it is important to study the third statistically significant explanatory variable; the number of participants on the Nord Pool Spot market. The variable indicates that as the market grows in terms of participants, prices decrease. When it comes to the market structure variables the full model indicates that the measures taken by the Nordic countries to create a common power exchange seem to have contributed to the liberalisation of the market and increased competition. On the other hand, no effect could be seen with regards to the other market structure variable measuring the cumulative market share of the main companies and this somewhat weakens the conclusion about a liberalised energy market.

In conclusion, both size and flow appear to be essential factors behind the electricity price level at the Nordic power exchange. The estimated results indicate that the flow of electricity and size in terms of participants on the market contribute to a decrease in spot price, while size in terms of traded volumes at the market contributes to an increase in spot price.

7.6 Alternative model – exclusion of cumulative market share data

As mentioned in the discussion regarding data, statistics on market share was only available between 2002 -2014 and the limited time dimension raised concerns for this study. To test if this affects the results the same models are run without the variable market share. Initially, the results look very similar to the ones presented in appendix II. However, when the full model is run, the coefficients for cross border flow and number of participants turn significantly positive. This weakens the previous conclusions about the negative relationship between the two variables and price and it means that the above presented results must be treated with caution. In contrast to what has been previously discussed about the negative effects of market integration, the alternative model indicates that all integration variables, as well as the variable measuring

participants on the market, have a positive effect on price, i.e. as market expand and flow across border intensifies, prices rise.

This could potentially be the result of a more precise modelling due to the increased number of observations in the alternative model. Although, it could also be explained by the fact that the market share variable is acting as a mediating variable, disturbing the causal relationship between the independent variables and price. This explanation is also strengthened considering the bivariate regression results in column one, table 7.1, where it is confirmed that market share is a significant predictor of the dependent variable and thus should be included in the model to avoid omitted variables bias.

Another observation worth mentioning is that the coefficient for generation structure becomes statistically significant in the alternative model. This strengthens the previous discussion about changes in generation structure and how it might affect the electricity price level. The increased significance level can be explained in similar terms as before and is probably to find in the fact that the alternative model represents the whole time period with data for 1996-2014. During the early years of Nord Pool there were large changes in generation structure due to new countries entering the market with different electricity production structures.

For the rest of the variables, the significance level increases which strengthens the previous conclusions about their effect on price.

Table 7.1 Estimated results for the Nord Pool Spot market. Spot price.

DV: ln(Electricity spot price, €/MWh)	Bivariate regressions	Multivariate regression without controls	Multivariate regression with controls
Explanatory variables			
Lagged dependent (t-1)	0.032*** (0.001)	0.022*** [0.001]	0.023*** [0.001]
ln(Traded volumes, MWh)	0.430*** (0.018)	0.174*** [0.048]	0.171*** [0.047]
ln(Cross border flow, MWh)	1.409*** (0.093)	-0.265** [0.129]	-0.745* [0.475]
Number of participants	0.003*** (0.0000)	-0.0009* [0.0005]	-0.002* [0.002]
Cum share of main entities	0.045*** (0.004)	0.011** [0.005]	0.057 [0.042]
Change in generation structure	-0.038*** (0.002)	0.0005 [0.003]	-0.011 [0.015]
Control variables			
Temperature (Celsius)	-0.048* (0.025)		0.089 [0.103]
Rain levels (mm)	-0.003*** (0.0003)		-0.0004 [0.0006]
Oil price (t-52)	.008*** (.0004)		0.005 [0.004]
ln(BNP per capita, €)	3.742*** (0.188)		-6.700 [6.071]
Constant	-	4.007	80.144
R-square (within)	-	0.86	0.86
Observations (N)	-	415	415

Significance: *p<0.1 **p<0.05 ***p<0.001

Source: Nord Pool FTP server, ENTSO-E annual statistics (2008), ENTO-E database, NordREG market integration reports, Swedish Energy AB, Eurostat.

8. Concluding discussion

8.1 How does multinational electricity market integration affect electricity prices at the Nordic power exchange?

This thesis has researched the effects of multinational electricity market integration on electricity prices at the Nordic power exchange. The theory behind the theoretical model presented in chapter five was that multinational power markets provide a number of distinctive benefits that would lower the spot price at the Nordic power exchange. It was pointed out that increased integration on multinational power markets provide more supply security, efficient use of installed capacity, lower trading costs and increased competition for the market participants – integration effects that were expected to ultimately lower the electricity price at the Nordic power exchange. A regression analysis was performed to explore the causal relationship between multinational electricity market integration and electricity price using weekly data from 1996 to 2014. Multinational integration was understood as an increase in volume traded at the Nord Pool Spot market and an increase in average flow of electricity across the Nordic borders.

As is clear from the models presented in the result section, multinational electricity market integration *does* have a significant effect on spot prices at the Nordic exchange market. Both size and flow matters for the price level, although not entirely as expected by the theoretical model. The integration variables actually appear to work in opposite directions and the overall effect of integration on price is therefore precarious to determine. The results indicate that increased flow of electricity across borders tends to drive down the electricity price while the size of the market in terms of total trade tends to drive up the price. In light of these results, it is interesting to note that there has been a rapid increase in traded volumes at the Nordic power exchange during recent years and that this is often said to be good for the customers. Yet, according to the results in this study, a rapid increase in traded volumes does not necessarily benefit the costumers in terms of lower electricity prices. Rather the opposite. In order to achieve lower electricity prices at the Nordic market, the results of this study instead points towards the importance of interconnectivity and transmission infrastructure. However, bear in mind that any generalization of the results should be done with caution since the alternative model provided slightly modified relationships.

Besides general findings about multinational market integration and its effect on price, the regression analysis also provided useful insights about the side effects of market integration and its relation to price. Looking at market concentration for example, the results indicated on the one hand that market integration helps to improve the conditions for the market to function effectively. There has been a steady increase of participants on the market, which proved to have a negative effect on price. Yet the number of participants is not a sufficient measurement of market concentration and no effect could be seen with regards to the other market structure variable measuring market shares. The widespread belief among regulators and policy analysts that deregulation and electricity market integration will yield competitive markets and lower electricity prices thus only seems to get limited support in this study.

Another integration effect that proved to have significant impact on price levels at the Nordic power exchange was changes in generation structure. The estimated results indicated that as the generation structure change at the Nordic electricity market and the generation portfolio of the region become more diversified, prices decrease. As was pointed out in the result section, this could potentially be a sign of less expensive power sources being the marginal source of electricity. Besides being an effect of integration, this could also be a result of a climate change policy leading towards more renewable capacity on the electricity market. Wind, solar and hydropower plants have no fuel or emission costs and if fossil fuelled plants are increasingly replaced by renewable sources the spot price is likely to decrease.

In summary, and as an answer to the research question of this study, I find that market integration does have a significant effect on electricity prices at the Nordic power exchange, although the policy measures undertaken by the Nordic countries to create a multinational power exchange have only been partially successful in lowering the price of electricity.

8.2 Further research

The research presented in this thesis gives answers to some questions regarding multinational electricity market integration, but in light of the rapid progress of the electricity market in both Scandinavia and Europe, new research questions emerge and previous research questions suddenly become obsolete. One of the aspects that this thesis does not take into account and that would

have been interesting to incorporate in a future analysis is congestion in the transmission system. Another aspect that is not included in this thesis is the foreign electricity import. If import is high it is plausible that this might affect prices and the functioning of the Nordic multinational market.

Potential subjects for future research also could include environmental aspects. In parallel to the creation of a single internal market for energy the EU is vigorously dealing with issues related to the Kyoto protocol and the promotion of renewable energies. These are aspects that may have important impact on the functioning of the wholesale markets across Europe and it would be interesting to analyse the impact of some of the incentive mechanisms for the promotion of renewable energy sources and how it affects price and competition on the Nordic power exchange.

Last but not least, the analysis presented in this thesis focuses on the Nordic electricity market but power exchanges are rapidly emerging in other parts of Europe as well. In light of this, it would be interesting to extend the analysis of market integration across EU and potentially study the wholesale market prices and the level of price convergence across Europe.

8.3 Importance of findings – future energy policy

From the general findings of this thesis there are some overall policy conclusions to be made. First, the effect of market integration on price points towards the importance of transmission infrastructure and the need for investments in cross-border capacities. If the available transmission capacity is not sufficient, flow of electricity is hindered and thus also competition and efficiency at the multinational market. Hence more investments in cross-border capacities are needed as it allows for a sustained effect of market integration. It is the distribution capacity that sets the upper limit for the trading levels and the exchange of electricity across borders hence it is distribution capacity that might hamper future market integration. Second, the change in generation structure following the market integration has been beneficial for wholesale prices. As such, companies should be incentivized to invest in more generation capacities to increase the diversity of the energy generation portfolio of the region. This may not only limit the price effects of a potential supply shock but also contribute to the lowering of electricity prices in general.

Extrapolating the results of this study towards the EU's ambiguous goal to create a single market for energy a few general lessons can be highlighted. The first lesson is that insufficient transmission capacity might restrain the benefits of integration and reduce the relevant market. The building of new transmission capacities takes time but will have to be prioritized, otherwise markets will become smaller instead of bigger – a development that is in sharp contrast to the intentions of the single market for electricity. The second lesson that can be learned from the Nordic experience and the results of this study is that trading with electricity is not the same as trading with other goods. This study has underlined a number of aggravating circumstances that make electricity a rather problematic case. For example, electricity is difficult and costly to store, the demand is inelastic and the market is partly network based and according to previous research, extra susceptible to strategic behaviour. These are issues that need to be taken into account when restructuring the electricity market and creating a single European electricity market. The EU cannot rely on the assumption that electricity is like any other good. Opening up markets and building new interconnection capacities definitely supports the liberalisation process since it increases the number of participants on the market, but it is not sufficient to create a single competitive market. The European electricity market is approaching new challenges where more specific questions about market design and technical standards need to be considered. These are complex issues that account for political considerations, technical constraints and economic efficiency aspects. A potential way forward, however, could be through the intermediate stage of regional markets. There are several recognisable regional markets in the EU today, although the Nordic market stands out as the most advanced in terms of effective multinational integration. Does this mean that the “Nordic model” should be adopted across all of the EU? The answer is not necessarily “yes”. The success of the Nordic countries could in many ways depend on area specific prerequisites such as ample supply of hydropower and a voluntary, informal commitment to public service by the power industry (Amundsen and Bergman, 2006:12). However it is without doubt that the national markets across Europe are progressively developing in the same manner as the Nordic countries, both physically and with respect to their regulatory framework, creating a new paradigm in the governance of electricity markets.

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Appendix I – Additional information on variables and dataset

Table 1. Missing data in dataset and descriptive statistics

Variable	Measured	Missing data	Obs	Mean	Min	Max
Electricity spot price	Weekly		987	30.97	4.83	103.65
Traded volumes	Weekly	2013	935	3607.10	555.90	8782.50
Cross border flow	Yearly	2009, 2014	884	6730.48	4508	9034.20
Number of participants	Yearly	1998, 1999 2001, 2007	780	284.87	148	377
Cum share of main entities	Yearly	1996-2002	624	48.17	38.66	50.47
Change in generation structure	Yearly		936	4.88	0	21

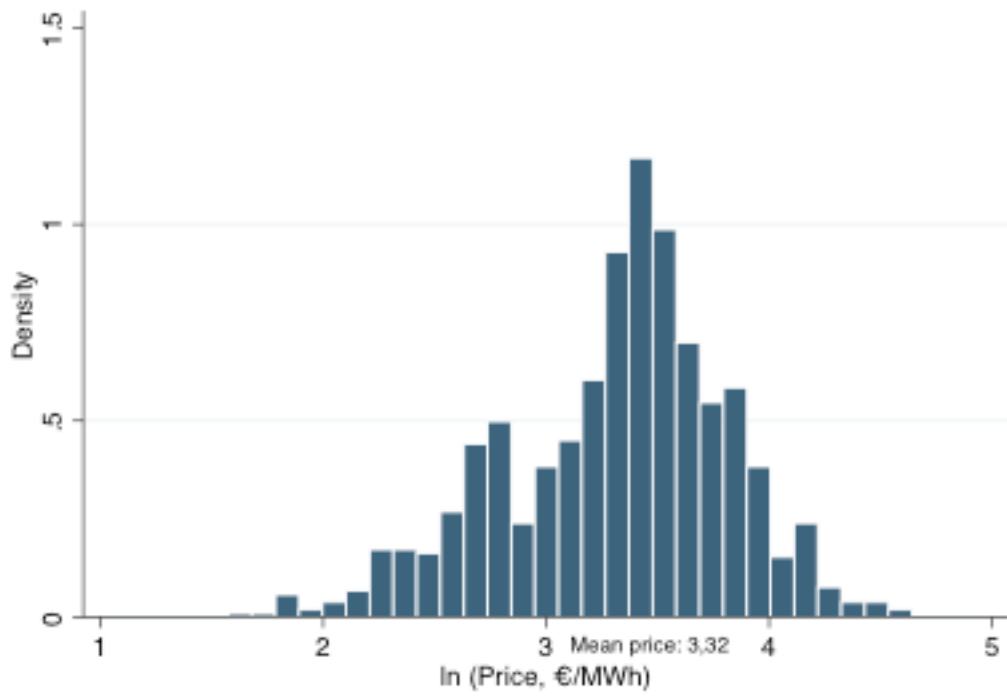
Table 2. VIF values

Variable	VIF	1/VIF
Number of participants	11.56	0.086
Cum share of main entities	7.11	0.141
Traded volumes	6.87	0.146
Change in generation structure	3.15	0.318
Cross border flow	2.28	0.439
Lag price	1.95	0.513
Mean VF	5.49	

Table 3. Coding of country borders

Border	To ←	→ To
1	Sweden	Finland
2	Sweden	Denmark
3	Sweden	Norway
4	Denmark	Norway
5	Norway	Finland

Figure 1. Frequency distribution of the dependent variable (€/MWh)



Appendix II – Regression results of alternative model

DV: ln(Electricity spot price, €/MWh)	Alternative multivariate regression³
Explanatory variables	
Lagged dependent (t-1)	0.021*** [0.001]
ln(Traded volume,MWh)	0.186*** [0.047]
ln(Cross border flow, MWh)	0.444** [0.175]
Number of participants	0.006*** [0.002]
Cum share of main entities	
Change in generation mixture	-0.011*** [0.001]
Control variables	
Temperature (Celsius)	0.094** [0.036]
Rain levels (mm)	-0.001*** [0.0002]
Oil price (t-52)	-0.009*** [0.002]
ln(BNP per capita, €)	-1.274 [0.830]
Constant	5.638
R-square (within)	0.89
Observations (N)	570

³ Excluding data on cumulative market share of main companies