Market Liberalization and Market Integration
Essays on the Nordic Electricity Market

Jens Lundgren
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Akademisk avhandling

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Abstract

This thesis consists of four self-contained papers related to the Nordic electricity market.

**Paper [I]** examine how the reform of the Nordic electricity markets has affected competition in the electric power supply market, Nord Pool. The question is if the common power market has been competitive or if electric power generators have had market power during the period 1996 -2004. Moreover, since there was a stepwise evolution from national markets to a multinational power market, we also ask how the degree of market power has evolved during this integration process. The results show that electric power generators have had a small, but statistically significant, degree of market power during the whole period. However, studying the integration effect, i.e. how the market power has been affected by additional countries joining Nord Pool, it show that the degree of market power has been reduced and finally vanished as the market has expanded and more countries joined the collaboration.

**Paper [II]** analyse how the deregulation of the Swedish electricity market has affected the price of electric power and how the change in electric power price, in turn, has affected consumers' welfare. The result shows that the change in pricing principle of electric power following the deregulation has increased consumer welfare over the period studied (1996-2006), with welfare gains about 100 SEK per customer per year, indicating a three per cent welfare gain for the average customer.

**Paper [III]** study whether (and to what extent) the Nordic multinational electricity market integration has affected the price dynamics at the Nordic power exchange. The results show that a larger electricity market seems to reduce the probability of sudden price jumps, but also that the effect on volatility seem to depend on the characteristics, i.e. production structure, of the integrated markets.

In **Paper [IV]** a two-stage study is conducted to investigate the extent to which shocks in the demand and supply for electricity translate into price jumps, and the extent to which this process is affected by the prevailing market structure. The main findings from the study is that whether demand and supply shocks translate into price jumps largely depends on the prevailing market structure, i.e. on how far the market works from capacity constraints. A notable feature of the empirical analysis is also that the marginal effects from positive demand and negative supply shocks on the jump probabilities are mostly insignificant and of small magnitude.

Keywords

Consumer welfare, Electricity price, Market integration, Market power, Price jump.
To Jenny, Leo and Ida
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Acknowledgments

It was in June 2002 I got accepted to the PhD-programme at the Department of Economics at Umeå University. Actually it was on my birthday I got the letter that confirmed that I was accepted. Thinking back to that day makes me nostalgic. I still remember it as if it were yesterday when telling my girlfriend (today my wife) and the rest of the family the great news at the birthday dinner.

A lot of things have happened since that day, the journey of life with all its adventures has taken me to many places, however most certainly not straightforward towards finalising this thesis. Obviously, I got a job before having finished this thesis. Looking back one might think that I regret stepping out in the “real” world before the thesis was completed. This is not the case. Sure it would have been nice to have finished earlier, but the experience from working hands on with energy questions has been most valuable. I honestly think that this thesis has benefited from my “real” world experience.

Finalising this thesis has taken longer than I initially planned. However, now it is finished and for that I owe gratitude to so many people.

First of all, I wish to thank my supervisor Niklas Rudholm for taken his job more seriously than I ever could have asked for. Niklas has encouraging me and never given up on me. I am grateful for that and also for all the guidance and for all the good comments on my work, and for always taking time for my numerous questions. I have also enjoyed our “working camps”, first in Gävle and later on in Borlänge. Thank you Niklas!

I would also like to thank my co-supervisor, and co-author to two of the papers, Jörgen Hellström. Thank you for good collaboration and for always taken time discussing and explaining our econometric models. It has been a privilege working with you.

There are many more great persons at the Department of Economics that I would like to thank, too many to list them all here. However, there are some I like to give some extra credit. First I would like to thank Runar Brännlund for his magnificent support, especially in the final phase of completing this thesis. Without Runars support the last few months I doubt that I would have managed to finalise this thesis. I would also like to thank Marie Hammarstedt who has helped me with administrative issues from day one as a PhD-student. Eva Cederblad also deserves credit for being an excellent administrator always ready to step in with help in difficult matters. I would also like to thank my PhD-student classmates for five really interesting years at the department. Most of all I like to thank my old roommate Lars Persson,
both for interesting academic discussions but also for all the good times discussing various aspects of the life of snowmobiling.

As I said I started to work before finishing this thesis. I have now worked for five years at the Energy Markets Inspectorate. It is a great place to work at, with many talented people having an enormous knowledge of how the energy markets functions. I owe gratitude to my colleagues for good discussions and comments on my work. I also would like to thank my boss, Tony Rosten, for excellent guidance in combining theoretical framework with the reality of the electricity market.

Although the people mentioned above are very important in the process of finalising this thesis I am sure that I never would have been able to finish it without the support from family and friends. I wish to thank my family for always supporting and believing in me, especially mum and dad. To my brother, thank you for reminding me of what is important in life and for keeping me grounded. To my parents-in-law, thank you for your kindness and for all your help.

To my dear friends Fredrik, Johan, Robert and Anders, I really appreciate our friendship. I definitely have enjoyed our adventures together and I am looking forward to all the adventures that will come in the future.

To my children Leo and Ida, thank you for setting life in perspective and for giving true meaning to my life.

Last but not least, to Jenny, my wife and the love of my life. Thank you for choosing to spend your life with me. There are not words enough to express how much I appreciate your support!

Umeå, November 2012
Jens

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1 It might be a good idea to clarify that the views expressed in this thesis are solely the responsibilities of the authors and should not in any way be viewed as reflecting the opinion of the Energy Markets Inspectorate.
This thesis consists of a summary and the following four self-contained papers


1 Introduction

Traditionally, a single utility provider has supplied all electricity within a geographic area. The utility was most often vertically integrated and responsible for the whole chain, production, transportation and delivery to customers. This situation has changed in recent decades. Deregulations in the electricity sector began in the late seventies and since then the electricity sector in several countries around the world has experienced structural changes. Deregulation of electricity markets in Europe started in England and Wales in 1990, when the industry was privatized and competition between generators was introduced. The England and Wales deregulation was followed by the deregulation of the Norwegian market in 1991 and in Sweden in 1996.

The deregulation in Sweden introduced competition between power generating companies through vertical separation of distribution across power supply and retail, as well as induced stepwise market integration with other Nordic markets. Whereas power supply and retail were set out to competition, distribution was left as a monopoly due to its characteristics as a natural monopoly. The main question raised in this thesis is how this deregulation, in terms of competition and increased market integration, has worked and affected market prices for electricity. The development of the various components of the electricity price from 1970 up to 2012 is displayed in Figure 1.

Figure 1: Price decomposition of the Swedish electricity price¹

¹ Price for a customer with 20 000 kWh yearly consumption, displayed in 2010 year prices.
Figure 1 reveals two interesting facts. The first is that the final consumer price (the sum of all components) has increased since 1996. The second is that the volatility in the price seems to have increased since 1996. Further inspection shows that taxes have gone up significantly while transmission costs have remained almost constant in real terms. Furthermore, additional environmental fees have been introduced during this period, e.g. green certificates in 2003 and the EU ETS in 2005. A tempting preliminary conclusion would then be that the main part of the increase in the consumer price level after the deregulation is due to increases in taxes and new environmental fees, whereas the increase in volatility seems to come from volatility in the power price itself. The main objective of this thesis is thus to further study the determinants and the development of the price level and price volatility, with a focus on the power price.

Following the market deregulation the market price of electric power is set in the Nordic multinational electric power exchange Nord Pool. This is combined with a shift from an average cost to a marginal cost pricing principle for wholesale electric power. With these changes in mind, one specific question posed is how the change of pricing principle has affected the price level and if this has changed the outcome in terms of market efficiency. A second specific question is raised by inspection of figure 1; can the new pricing principle explain the increase in price volatility with higher spikes and lower bottoms after 1996? In other words, has the change in the pricing scheme induced competition between electric power suppliers, and hence contributed to lower prices, and has it altered the price dynamics?

The papers in this thesis start with the change of pricing principles of electric power in the Nordic power exchange, Nord Pool, by addressing questions like the ones above. The papers cover three areas of the electricity market that all have the ability to cause market inefficiencies, and hence also lower customers welfare relative to what could be achieved in the best of circumstances. Although there exists a fairly extensive literature analysing electricity markets, the papers in this thesis contribute to the existing literature by addressing questions that have not previously been addressed.

First, with the new market setup determining prices at the power exchange, there are new ways of exploring market power. Previous literature, e.g. Green and Newbery (1992), Andersson and Bergman (1995) and Rudkevich et al (1998), concluded that electric power markets are vulnerable to market power. If this is also the case in Nord Pool, consumers will be charged market prices above marginal cost, which in turn will result in an inefficient allocation of resources. In the first paper in this thesis, the level of market power, i.e. the possibility for firms to charge a price above marginal

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2 The increase in price volatility becomes even more apparent if we look at daily, weekly or monthly electricity prices.
cost in the Nord Pool spot market, is analysed. This is interesting due to the fact that the new market structure introduced new conditions for competition in power generation and that over the years the size of the power market has expanded as more countries joined the Nord Pool collaboration. Previous literature, e.g. Johnsen et al (1999), Hjalmarsson (2000), Vassiopoulus (2003), Steen (2003) and Damsgaard et al. (2007), studied market power in the Nordic power market. Fridolfsson and Tangerås (2009) reviews the efforts made in analysing the Nordic electric power market. However, neither of these nor any other previous papers evaluate the effects of the market integration process on market power in the Nordic power market. Amundsen and Bergman (2007) analysis the integration process but not the market power due to it.

There are studies of other power exchange markets besides the Nordic, e.g. Green and Newbery (1992), Wolfram (1999) and Wolak (2003). Although this thesis is a case study of the Nordic electricity market it has some bearing in a more general setting. That is, experience of the Nordic case can be of use in the integration process of electricity markets in other regions, especially within the European Union.

Secondly, even if the Nord Pool spot market is found to be competitive, the change in pricing principle for electric power to marginal cost pricing³ may have affected the level of the electricity price. Since this electricity power price level is the base of what consumers pay for electricity, it is interesting to study to what extent the change in pricing scheme has affected prices and also consumer welfare. Kwoka (2008) sets up 4 different approaches for analysing the effects of deregulations. The first approach is a direct comparison of the deregulated market with the underegulated market. 4 This is also the approach in which paper II analyses the effect on consumers’ welfare through shift in the pricing principle of electric power. Existing literature analysing the effects of the deregulation in Sweden is not that extensive, but two articles on the matter are Bowitz et al (2000) and Damsgaard and Green (2005) which each use the first approach of Kwoka (2008). More recently Brännlund et al (2012) published a report analysing the effects regarding market efficiency and the price effects of the deregulation. Their approach is somewhat different as it is based on econometric modelling and falls under the fourth approach of Kwoka (2008).

³ Before the deregulation, the pricing principle on the Swedish high voltage electric power market was approximately average cost pricing. After the deregulation, the pricing principle changed to marginal cost pricing.

⁴ The other three approaches are 1; examine the effects of variations in the intensity of regulation across time and place, 2; controlled experiment, 3; econometric modelling based on underlying demand, costs, and other relevant behavioural relationships.
Thirdly, even if competition is working in the Nord Pool spot market, and the marginal cost pricing principle has increased consumer welfare, it's likely (see the discussion regarding Figure 1) that marginal cost pricing has led to a higher volatility in the electricity power price than before the deregulation. Higher volatility creates uncertainty and possible disutility for consumers as well as producers. Consumers, assumed to be risk averse, are likely to prefer stable electricity prices rather than volatile, since it creates less uncertainty about future electricity costs. Producers, noting that on a deregulated market retailers can no longer pass cost through to customers without the risk of losing them, may end up with higher costs. For electric power producers the recovery of investments in, for example a new plant, is thus no longer guaranteed. Altogether, risk management has become a new and important part of the electricity business. In the third paper of the thesis the dynamics of electricity prices in the Nordic power exchange, Nord Pool, are empirically explored. More specifically the price dynamics are analysed in the context of the multinational Nordic market integration. Previous literature, e.g. Huisman and Mahieu (2003) and Bystöm (2005) has analysed electricity price dynamics, but to the author’s knowledge this is the first paper analyzing the effects of multinational power market integration on electricity price dynamics.

Paper IV continues where paper III ends. That is, one question left unanswered in paper III was the cause of electricity price jumps. In the previous literature on electricity price dynamics the occurrence of electricity price jumps is often loosely motivated by shocks to the electricity demand or to an inelastic electricity supply, e.g. Huisman and Mahieu (2003), Byström (2005), Gunthrie and Videback (2007) and paper III. As such, the purpose of paper IV is to empirically explore the possible causes behind electricity price jumps in the Nordic electricity market. To the author’s knowledge the possible causes for electricity price jumps have not previously been formally studied.

The Swedish electricity market prior to the deregulation

Prior to the deregulation of the Swedish electricity market in 1996, the market in Sweden was characterized by vertically integrated monopolies, active in local or regional settings, producing electric power as well as selling electricity to customers and running the distribution network. An effect of the market rules was that there was no competition between the utilities at any level; generation, retail or distribution (SPK 1989:8). Thus, the incumbent retailer was the only firm selling electricity to customers in that area.

5 That is, relatively large sudden increases or decreases in the electricity price.
The electricity market before the deregulation was divided based on customer characteristics into a high and low voltage market. The high voltage market was a market for generators, large industries and retail distributors, while the low voltage market was a market for retail distributors and their consumers, mainly households (Bergman et al, 1994). As a customer in the low voltage market it was not possible to change supplier, the customer was stuck with the incumbent firm in the area where the customer lived. The vertical integration also meant that retailers to a large extent bought the electricity they sold to their customers from the vertically integrated power generator.

In addition to the high voltage market, there was a market handling short term energy exchange between generators. This market worked like an "electric power pool" and was characterized by extensive cooperation and information exchange between the participants. Generators, the members of the pool, with a shortage or surplus of power could buy or sell power from the "power pool", respectively. The exchange price was based on the so called split-savings principle, a method where the price was determined by the average of the buying firms’ marginal cost and the selling firms’ marginal cost (Hjalmarsson, 1996).

The high voltage market, where the state owned company Vattenfall was the dominating actor with 50 per cent of the generation capacity, was not directly regulated. Government regulation was instead implemented through the control of Vattenfall. Pricing was indirectly regulated through the state-ownership of Vattenfall and the requirements on the firm’s pricing formula. Vattenfall was required to apply pricing formulas that can be seen as marginal cost pricing subject to rate of return requirement and budget constraints, with a formal objective to break even. This established Vattenfall as the price leader on the high-voltage market and also worked to set a price ceiling. The generators’ collaboration in the "power pool" resulted in a price floor which also prevented further entry to the market (Bergman et al, 1994).

More specifically, the pricing in the high voltage market was conducted through high voltage tariffs consisting of four elements: a fixed fee, a contractual demand charge, a peak load charge and an energy charge (SPK, 1989:8). The energy and the peak load charge were priced by marginal cost while the contractual charge and the fixed charge were determined by the rate of return requirements and budget constraints. The pricing method was rather efficient resulting in prices not much higher than marginal cost prices (Bergman et al, 1994). However, the pricing mechanism in the high voltage

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6 The required return was equal to the depreciation on replacement values and a rate of interest on loans from the government at the bond rate level.
market consisting of both marginal cost and fixed fees could be viewed as an approximation to average cost pricing.

This is also argued by Damsgaard and Green (2005) who say that the required rate of return restriction on state- and municipality-owned generators makes average cost pricing a reasonable approximation of the pricing principle on the high voltage market before deregulation. The split-saving principle used in the “power pool” before deregulation give further support that the price on electric power could be approximated by average cost pricing.

It should also be mentioned that the Nordic countries, Denmark, Finland, Norway and Sweden had started cooperation in electric power supply several years before the deregulation. That is, there were interconnectors between the countries which were used, as today, to transport electric power between countries when needed.

**The Nordic electricity market after the deregulation**

The political discussion to liberalize the Swedish electricity market began in the early 1990s. After a time of political controversies, new legislation was adopted and in 1996 the Swedish electricity market was deregulated. The process was the result of a combination of national initiatives and demands from the EU. The aim of deregulation was to create a well-functioning electricity market with competition in electric power production and retail. Distribution remained a monopoly market, but third party access was introduced. Legal unbundling between power production and distribution was also introduced to encourage competition. To invoke additional competition in the electric power market, collaboration with Norway in the Nord Pool market was introduced.

In 1996 the first directive concerning common rules for the internal market in electricity (96/92/EC) was presented. The enlargement of the Nordic electricity market is partly a result of this directive. The first directive is also the start of an era where the development in the electricity market is driven by the European Community, and national initiatives are becoming less important. The first directive has since been replaced by second and a third directives (2003/54/EC and 2009/72/EC respectively). These directives and the internal European electricity market are the primary driving forces for the electricity market, but the Renewable Directive (2009/28/EC) also plays a role as the issue of climate change in the last few years has become a challenge for the electricity markets.

**The Nordic power exchange**

At the time Sweden deregulated its electricity market, a similar process was ongoing in Denmark and Finland. In Norway, a deregulated market was already in place. When Sweden joined the Norwegian power exchange
market in 1996, the world’s first international power exchange, Nord Pool, was created. The power exchange market was expanded when Finland and Denmark entered Nord Pool in 1998 and 2000 respectively. Since then the Nord Pool area has continued to grow and today this includes collaboration with Germany, the Netherlands, Poland and the Baltic states.

The introduction of Nord Pool affected how the electric power market functions. Even if there were collaborations before the establishment of the Nord Pool power exchange, this new collaboration affected all participants in the market providing a formal market place where the price of power was determined. This meant that the participating countries’ electric power generators had to compete with generators from the whole Nord Pool area instead of acting as monopolists in their own local area. Secondly, as the market for electric power expanded, one consequence was that the large electric power generators in the individual countries got smaller market shares in the common market. For example in year 2004, the four largest electric power generators in Sweden covered 88 per cent of the Swedish market (with Vattenfall as largest firm covering 47 per cent), while in the Nord Pool area the four electric power generators covered only 48 per cent of the total market (with Vattenfall as the largest firm with 19 per cent). Thus, the larger electric power market improved the conditions for the market to function effectively without abuse of market power. However, the outcome of the markets functioning is closely related to the transmission network and congestion therein. This issue is discussed in the next section.

The Nordic electric power market is a combination of several markets. The first market is the non-mandatory Nordic power exchange, Nord Pool. In short, Nord Pool handles the day ahead spot market for physical contracts, Elspot. The second market is a market that handles bilateral contracts. In this market, electricity contracts are handled and settled between two parties, a buyer and a seller, without intermediaries. In addition to these markets there is a financial derivatives market, which handles futures, forwards and option contracts. The system spot price plays an important role in the Nordic power market, as it also function as a reference price for the bilateral and financial contracts. The spot market has increased its volume turnover, from handling 16 per cent of the electricity consumed in the area in 1996 to about 70 per cent in 2011.

As the Nord Pool spot market handles a large portion of the electricity consumed in the area, and functions as a reference price for bilateral and

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7 Swedenergy (2005).
8 To be precise it should be said that the market for physical deliveries actually consists of the day ahead market, Elspot and the intraday market, Elbas. Initially the intraday market only covered Sweden but it has expanded and now covering the Nordic region, Germany and Estonia.
9 As from 2010 Nasdaq OMX owns and operate the financial derivatives market.
10 Nordpoolspot (2011).
financial contracts, Nord Pool has a vital function in the electric power market. In the Nordic electric power market, the electric power price is settled in the one day ahead spot market at Nord Pool. The pricing principle in the spot market is a single price, double auction model where the system price is set hour by hour by the intersection of demand and supply bids. In Figure 2 below, the relative marginal cost and supply are presented.

The supply bidders (electricity power generators) bid in how much they are willing to sell and at what price. If the market is working, the generators bid should be based on their marginal cost of production. The merit order in Figure 2 is also based on the marginal costs for different production technologies and shows when different production sources are used for production. Demand on the other hand, is a function of how much electricity is needed at the moment. Household demand is determined by, among other things, outside temperature (electricity for heating purposes) and how dark it is outside (electricity for lighting). For the industrial sector, electricity demand is generally determined by the economic situation, with lower energy demand in recessions.

**Figure 2: Merit order and marginal cost in the Nordic electric power market**

![Diagram showing merit order and marginal cost](image)

Source: The Energy Markets Inspectorate

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11 The relevant marginal cost is the short run marginal cost of electric power production, including relevant cost of production (different for different power plants) e.g. fuel costs and EU-ETS allowances costs. For hydro power production the relevant cost is not the marginal cost (which is nearly zero). Instead the production decision is based on the calculated “water value”. The water value is a complex calculation based on parameters such as future inflow and expected prices.
The market clearing price in the day ahead market will be where demand and supply intersect. The price will be set at the marginal cost of the marginal bid, i.e. the bid that clears the market. The pricing principle also means that all suppliers that get their bids accepted (bids lower than the marginal bid, i.e. in Figure 2 to the left of the intersection) get paid the market clearing price. Also, the consumers have to pay the market clearing price. Given that no one can exercise market power, the pricing principle used is efficient, even though it allows firms with low marginal cost of production to earn extra profits.

In the case shown in Figure 2 suppliers with sources such as wind or hydro production have a lower marginal cost than the market clearing price. For these firms the difference between their marginal cost and the market clearing price will contribute to cover their fixed cost and to their short run profit. A normal misconception is that this profit is due to abuse of market power, however, it is not. These profits are due to the usage of production sources with lower marginal cost than the production source setting the price. In this sense the electricity market is supposed to work like any other competitive market. The issue of market power is an issue of whether a single producer (or a group of producers) can act strategically in the sense that they can affect the market price through their supply bids. There are thus two different questions where the market power issue is discussed in paper I.

Transmission capacity and bottlenecks
In the previous chapter it was mentioned that the transmission network could affect the market outcome due to congestion. A fundamental feature of electricity is that it is produced in power plants and then transported to the customers through a transmission network. To handle the fact that transmission lines have limitations in their transport capacity and from time to time will be congested, the Elspot market is divided into several bidding areas. As of 1 November 2011 Sweden consists of four bidding areas and the Nord Pool area in total of 13 bidding areas. The Nord Pool system is built such that if there is no congestion between the bidding areas, the whole Nord Pool area will have the same price. However, if the available transmission capacity is not sufficient, the flow of power between the bidding areas will be congested and different area prices will be established. So, even if supply and demand are the key factors determining the hourly market prices, available transmission capacity will also play a role. That is, to relieve the congestion different area prices are introduced and the price is raised to reduce demand in the areas affected.

12 For further discussion regarding marginal cost pricing and other potential pricing schemes for electric power exchanges see e.g. Gómez and Rothwell (2003) or Stoft (2002).
One effect of congestion on transmission lines is, as described above, that different bidding areas get different prices. In addition, congestion also implies that the relevant market area will be limited to the bidding areas that have no congestion between them. This will have implications for competition in the Nord Pool area in that the electric power generators in the smaller areas will get larger market share in those areas during the hours the transmission lines are congested.\(^\text{13}\)

In the process towards an internal European electricity market linking different regions together is crucial. For this purpose market coupling of different regions is undertaken. This involves making all cross-border transmission capacities available to all market participants, and that energy transactions between the participating power exchanges can be done by connecting their price calculations.\(^\text{14}\) To support market coupling and ensure that the different areas will receive equal prices, transmission capacity has to expand and the bottlenecks have to be removed. The building of new transmission capacities in Europe is in progress, although the process takes time. One problem is if transmission capacity is not sufficient, since this, as discussed above, will reduce the relevant market. This would be in conflict with the intentions of a single internal market for electricity in the sense that markets effectively become smaller instead of bigger.

**The Swedish electric power production structure**

Since the introduction of nuclear power plants in the 1970s and 1980s, electric power generation in Sweden has consisted primarily of hydro- and nuclear power, which cover approximately 90 per cent of Swedish power generation on a yearly basis.

The electric power generation mixture in Sweden did not change much between the years 1995-2006 (Table 1). However, integration with other countries has resulted in an increased flow of electric power across borders. As such, the production mixture of neighbouring countries is also to some extent imported. Moreover, the production mixture varies from year to year, mostly due to how precipitation influences hydro power production. For example, year 2000 was a year with high precipitation, resulting in hydro power production above average in Sweden. On the other hand, 2003 was instead a year with low precipitation and all time low levels in the reservoirs. In recent years it can also be seen that more wind power is coming in to the system, probably due to the introduction of the green certificate system.

\(^\text{13}\) See e.g. Steen et al (2003) or Energy Markets Inspectorate (2012) for an elaborate discussion on bottlenecks, relevant market size and market power.

\(^\text{14}\) See e.g. nordpoolspot.com for an elaborate discussion.
Table 1: Electricity production in Sweden 1995-2011, percentage

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<th>Hydro</th>
<th>Nuclear</th>
<th>Wind</th>
<th>Other*</th>
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<td>-0.01</td>
</tr>
<tr>
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<td>0.01</td>
<td>0.08</td>
<td>-0.05</td>
</tr>
<tr>
<td>2006</td>
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<td>0.45</td>
<td>0.01</td>
<td>0.09</td>
<td>0.04</td>
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<tr>
<td>2007</td>
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<tr>
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</table>

*Includes i.e. CHP, industrial back-pressure and Gas-turbines  **Negative sign equals net export

Source: Statistics Sweden (SCB)

2 Summary of the papers


In the first paper of this thesis we examine how the reform of the Nordic electricity markets has worked in terms of competition in the electric power supply market. Our question is whether the deregulation has been successful: has the common power market been competitive or have electricity suppliers had market power? Moreover, since there was a stepwise evolution from national markets to a multi-national and largely deregulated power market, we also ask how the degree of market power has evolved during this integration process.

A straightforward measure of market competitiveness is the price-marginal cost markup; since it is zero in a perfectly competitive market, meaning that the electricity price should equal the production cost of the marginal unit of production. However, even though market prices are easily accessible in the Nordic power market, this is not the case with marginal
costs and therefore some other method must be used to measure the degree of market power.

In the study, a conjectural variation method named the Bresnahan (1982) and Lau (1982) method is used. This model does not need knowledge of marginal cost to calculate market power. The Bresnahan – Lau model instead allows for identification of market power using aggregated industry data. The model implies that conjectural variation elasticities are estimated and used to identify the level of market power. The conjectural variation elasticity at the industry level is the average of the individual firms' conjectural variation elasticities, which measure the firms' output response to the single firms output change as conjectured by this firm. Thus, if there is perfect competition, there is no output response since a single firm cannot affect output at the industry level, whereas the response is one-to-one if there is no competition since the industry behaves as a single firm. The conjectural variation elasticity is estimated from a two-equation system, where the first equation is electricity demand as a function of electricity price and at least one exogenous variable. The second equation is electricity supply, derived from profit maximization, which is the electricity price as a function of industry output, the same exogenous variables as for electricity demand and other exogenous variables. The data set used consists of weekly data from all Nord Pool participants, covering the period from week 1 in 1996 to week 16 in 2004. The price variable is the Nord Pool spot price at the system level.

The results show that electric power generators have had a small, but statistically significant, degree of market power during the whole period. However, the results from analysing the integration effect, i.e. how the market power has been affected by additional countries joining Nord Pool, show that the degree of market power has been reduced as the market has expanded and more countries joined the collaboration. In the last subperiod (2002-2004), when both Finland and Denmark had entered Nord Pool together with Sweden and Norway, the results show that there was no statistically significant market power present in the Nordic electric power market. In economic terms, the implied Lerner index gives a markup of less than one per cent in the different subperiods and an even smaller markup for the whole period. This means that compared to the case of perfect competition the price at Nord Pool is one per cent higher. One interpretation of the calculated markup is that the impact of market power on the electricity price has not been that severe and that the Nord Pool market has worked rather well.

Our results are in line with previous studies (e.g. Hjalmarsson, 2000 and Vassilopoulos, 2003) in that all found little or no evidence of market power. Fridolfsson and Tangerås (2009) conducted a survey over research regarding market power in electric power markets that also concluded that there is no
evidence from the literature of any systematic abuse of market power in the Nordic electric power market. Brännlund et al (2012) performed an econometric study of the Nordic electric power market concluding that the market seems to function as an effective market is supposed to.

**Paper [II] Consumer Welfare in the Deregulated Swedish Electricity Market**

From the first paper in this thesis, we know that the spot market at Nord Pool has been characterised by a low degree of market power. However, ten years after the reform high electricity prices in Sweden have sparked a debate that portrays the electricity market deregulation as the cause of high consumer prices and large producer profits. How are high prices consistent with the results that the Nord Pool power exchange shows no evidence of market power abuse?

The second paper in this thesis analyses how the deregulation of the Swedish electricity market has affected the price of electric power and how the electric power price, in turn, has affected consumers’ welfare. The study uses an equivalent variation approach and the analysis is performed using monthly data, covering the period from January 1996 to January 2007. The equivalent variation approach, which is an exact welfare measure, allow us to answer the question of how deregulation has affected consumers’ welfare through shifts in the electric power price, where the actual price after the deregulation is compared to a hypothetical price path in absence of the deregulation. This alternative and hypothetical price path is based on the regulation guiding the Swedish power prices before 1996. The difference between the alternative price and the prevailing Swedish area price is then used to calculate the effects on consumer welfare, making it possible to quantify the effects on consumer welfare from changes in the electric power price, while excluding the impact of tax increases and other governmental interventions such as the effects of introducing green certificates (in 2003) and the EU Emissions Trading System (in 2005).

To construct the alternative price path it is important to understand how the pre-deregulated price was determined, since that should be the base for the alternative price. The pricing principle was described in the introduction, and could be approximated by average cost pricing. In this paper, average cost of electric power production is measured by the producer price index (PPI) for electricity production, and since the pricing principle in the regulated market can be approximated as average cost pricing (e.g. Damsgaard and Green (2005)), the PPI for electricity production will be used to derive the alternative price path if the market had not been deregulated. To convert the PPI from index form to a price path, the January 1996 power price is used as the base. That is, the January 1996 electric power
price is multiplied with the PPI for each month to get a price path that shows what the price would have been without the deregulation. The two alternative price paths are presented in Figure 3 below.

**Figure 3: Price comparison, 1996-2007**

![Price comparison graph](attachment:image.png)

Source: Nord Pool and own calculation

To measure the effects on consumer welfare, the prevailing Swedish area price is compared to the alternative price path. The calculated EV-measure reveals that consumer welfare has increased by 4 billion SEK in 1996 prices over the period studied. Calculation shows the consumer welfare gains are less than 100 SEK per consumer per year, indicating a welfare gain just below three per cent for the average customer. Sensitivity analysis using alternative scenarios also support the conclusion that for the period studied the deregulation has increased, not decreased, welfare for the Swedish electricity consumers.

The finding of positive welfare effects is in line with previous literature (e.g. Bowitz et al, 2000 and Damsgaard and Green, 2005). The result is also consistent with Brännlund et al (2012), who, using a econometric approach, also find that higher consumer prices that have been observed since deregulation in large can be explained by increases in input prices and increasing tax levels, and not by the deregulation.
Paper [III] Multinational Electricity Market Integration and Electricity Price Dynamics

In the first paper of this thesis it has been shown that the Nord Pool power exchange has not been characterized by market power. It was shown that initially there were some minor problems with market power, but that expansion into a larger market seems to have reduced the problems. In the second paper it was shown that consumer welfare on average has not been affected to any large extent by the deregulation and the introduction of the new pricing scheme. However, as compared to a regulated market with prices reflecting average rather than marginal costs, it could be expected that the deregulated market has a higher volatility in prices. Higher volatility creates uncertainty for both consumers as well as producers, uncertainty that could affect both negatively.

Paper III empirically studies whether and to what extent the Nordic multinational electricity market integration has affected the electricity price dynamics on the Nordic power exchange. In particular, the focus is on determining what effect the multinational market integration, during the years 1996-2006 has had on the conditional mean electricity price, upon the conditional variance, upon the mean jump-intensity (expected frequency of larger price movements) and on the mean jump size. The question of how the multinational market integration has affected electricity price dynamics is of particular importance in light of the commitment within Europe towards further integration of other European electricity markets. An understanding of the effects of electricity market integration on electricity price dynamics will help participants, as well as decision makers, to build better expectations about the effects of future integration on electricity price dynamics.

Previous studies concerning electricity price dynamics, e.g. Byström (2005) and Guthrie and Videback (2007), have established a number of salient features concerning electricity price dynamics: (i) Mean reversion to the long-run equilibrium price level (reflecting the marginal cost of producing electricity) exists; (ii) Large daily volatilities (compared to financial price/return series) and volatility clustering is present; (iii) Jumps (large price changes) are frequently encountered; (iv) Price series show strong seasonal patterns mainly due to the strong dependence of electricity demand on weather conditions. In order to capture these features of electricity price dynamics a mixed EGARCH-jump model is utilized in the empirical study. The conditional mean specification (excluding contributions from jumps) of the electricity price includes autoregressive components reflecting mean reversion, as well as weather variables capturing seasonal effects. The time varying conditional variance component (EGARCH)
captures the smooth changes in volatility and allows for volatility clustering. The jump component explains the more infrequent larger price movements. The model allows for both positive as well as negative jumps, i.e. a mean jump size permitted to be either positive or negative is estimated, which is important for electricity price modeling since large jumps are often followed by a reverse price jump.

Empirically the study reveals that the conditional mean electricity price increased when Finland entered, and remained at this higher level when Denmark also joined. Turning to the price volatility, this increased with Finland’s entrance, but decreased when Denmark joined. However, the price jump-intensity decreased both when Finland and Denmark entered the market. In short, this means that a larger electricity market seems to reduce the probability of sudden price jumps, but also that the effect on volatility seem to depend on the characteristics, i.e. production structure, of the integrated markets.


In the third paper in the thesis, we found that the multinational electricity market integration seems to have created a market that handles external shocks to supply and demand more efficient than the separate national markets previously did. However, one question that was left unanswered in paper III was the cause of electricity price jumps. As such, the purpose of paper IV is to empirically explore the possible causes behind electricity price jumps in the Nordic electricity market. The question is analysed empirically using essentially the same data set as in paper III, covering 1996-2006.

For people working with risk management, portfolio management and electricity derivate pricing an understanding of electricity price dynamics is crucial when doing business. Since electricity is not a storable good the conventional derivatives pricing models based on Black-Scholes model are not appropriate. Instead valuation of electricity derivatives is dependent on models that properly describe the dynamics of the underlying electricity spot price (e.g. Huisman and Mahieu, 2003). As a consequence a literature (e.g Pilipovic, 1998; Lucia and Swartz, 2002; Huisman and Mahieu, 2003; Byström, 2005; Guthrie and Videback, 2007) has emerged focusing on characterizing electricity price dynamics.

One of the well documented features of electricity prices in the literature concerns the frequent occurrence of large price changes or jumps. The occurrence of electricity price jumps is often loosely motivated by shocks to the electricity demand or to an inelastic electricity supply, but these possible causes for price jumps have, to the author’s knowledge, not previously been formally studied. In paper IV, a two-stage study is conducted to investigate
the extent to which shocks in the demand and supply for electricity translate into electricity price jumps, and the extent to which this process is affected by the prevailing market structure.

A mixed GARCH-EARIJ jump model is utilized in the first stage to identify electricity price jumps by properly separating “normal” variation from that caused by price jumps. In the second stage ordered probit models with the identified price jumps as the dependent variable are utilized to empirically study the question at issue. The used proxies for exogenous demand and supply shocks are day to day changes in temperature and in nuclear power production, respectively.

The main findings from the study is that whether demand and supply shocks translate into electricity price jumps largely depends on the prevailing market structure, i.e. on how far the market works from capacity constraints. This result is loosely consistent with the perspective considered in Paper III in that the price volatility and jump probabilities will be determined by how close to the capacity constraints the market is working. Through a simple supply and demand analysis at an aggregate level it can be seen in Figure 4 that, after Finland entered the Nord Pool collaboration (Period 2), the intersection of demand and supply was relatively closer to the capacity constraint, in which price jumps, in particular positive jumps, are more likely to occur.

**Figure 4: Electricity supply and demand in the Nord Pool area**

![Graph showing electricity supply and demand in the Nord Pool area](image)

Source: Nordel and own calculation

However, after Denmark entered Nord Pool (Period 3), the intersection was shifted somewhat further away from the capacity constraint. Such a
movement would mitigate the impact from temporary positive demand shocks, which in turn decreases the probability of positive price jumps. A notable feature of the empirical analysis is also that the marginal effects from positive demand and negative supply shocks on the jump probabilities are mostly insignificant and of small magnitude.

3 General findings and policy implications

Paper I analysed the presence of market power at Nord Pool. The main conclusion is that pricing in the Nord Pool works relatively well and that market power has been reduced as the market has grown larger. The policy conclusion here is that larger electric power markets work better to prevent the exercise of market power. The conclusion should remain even today since it is based on basic economic principles that more companies in a market create better conditions for competition.

However, it should be noted that the results in paper I are based on aggregated prices at the system price level with no transmission constraints. Thus, the results does not say anything about how the competition work in shorter time spans and how competition is affected if transmission is congested resulting in several price areas. Since the analysis is based on a weekly average data, use of market power in shorter terms than that are not analysed. However, systematic use of market power in shorter time periods should be, if it is extensive, visible even in an aggregate analysis. Thus, the fact that the analysis at the aggregated level only show a small impact of use of market power indicate that any abuse also should have a small impact for shorter time frames.

The transmission constraint issue is that congested transmission lines create separate price areas and thus several smaller markets. This could have impact on the competitive behavior in the market. One example is the introduction of four bidding areas in Sweden in 2011, dividing Sweden into smaller price areas when transmission capacity within Sweden is not sufficient. Previous research (Steen, 2003, Damsgaard et al, 2007) has shown that congestion on transmission lines can affect how firms act and market outcomes. However, upcoming market development, with increased transmission capacity and possibly more active customers, can further reduce potential market abuse. One conclusion that can be drawn from paper I regarding this discussion is that given that there is sufficient transmission capacity, competition will take place in a larger market, and accordingly work better. On the other hand one can also say that a deregulation which opens up competition probably is not sufficient for achieving an efficient competitive market as long as there exists severe limitations in transmission capacity. Finally, development after 2007 also implicates more intermittent power in the system. How this development...
affects the prices and the market’s ability to withstand market power is out of the scope of the thesis since the data used does not cover this time span. However, it does not seem very bold to say that short run price volatility will increase in the future. This matter is discussed in e.g. Mauritzen (2010) and Twomey and Neuhoff (2010).

Paper II in this thesis analysed how the deregulation of the Swedish electricity market has affected the price of electric power and how the shift in the pricing scheme, in turn, has affected consumers’ welfare. The conclusion of the analysis is that the deregulation has affected the well-being positively. This is also in line with previous literature, e.g. Bowitz et al (2000), Damsgaard and Green (2005). Brännlund et al (2012) uses an econometric approach also finding that the deregulation did not affect consumers’ welfare negatively.

One reason for the result is that while the price path under deregulation has been volatile with both dips and peaks, the alternative price has been more stable but at a higher price level. The less volatile alternative price path is due to differences in the pricing methods. The deregulated price is more volatile because the price is determined by supply and demand in a competitive environment, and set equal to the cost of the marginal unit of energy production necessary to meet demand, while the pre-deregulated price resembled average cost pricing. The average cost based price does not fluctuate as much as the marginal unit based price because a sudden demand increase (decrease) – and the subsequent price jump (dip) – is averaged out by the other facilities. In the deregulated case, a sudden demand increase will instead allow those generation facilities with a marginal cost lower than the marginal facility, to increase their profits.

The main policy conclusions of paper II is that the change in pricing mechanism has been to the benefit of the customers. An assumption of the analysis was that the production structure in Sweden did not change dramatically after the deregulation, which also is shown in Table 1. If the production structure had changed it would be more difficult to draw conclusions regarding the price changes. In the light of climate change and how it has affected policies regarding electric power generation, leading to more renewable energy sources, the electricity power mixture has started to change after 2007. This could be a reason to re-evaluate the impact of the pricing scheme change after the deregulation. However, in terms of welfare changes, the new policy regarding renewables has nothing to do with the change of pricing principle following the deregulation as such and should therefore not be incorporated in the welfare analyses of the impact of the deregulation.

In paper III, we empirically studied whether and to what extent the Nordic multinational electricity market integration has affected electricity price dynamics in Nord Pool. The results indicated that a larger electricity market
seems to lower the probability of sudden price jumps, but that the effect on volatility depends on the production structure of the integrated markets. This implies that multinational electricity market integration seems to have created a market that handles external shocks to supply and demand more efficient than the separate national markets previously did.

However, the conclusion that a larger electric power market will lower the probability of price jumps and handle external shocks more efficiently, rests on an implicit assumption that the interconnection between areas are strong enough to keep the different areas together as one. With the focus on an internal European market for electricity new interconnectors are built and the transmission capacity strengthened. As such the policy implication of paper III still holds and is of even more relevance today and in the future than during the studied period.

The conclusions in paper III that the price volatility will be determined by how close to the capacity constraint the market is working and that the size of the price jumps also depend on the capacity constraint in the market are still valid today. The result is driven by different costs of operating the different power plants. Baseload electric power is relatively cheap but when the market is moving towards the capacity limit more expensive electric power is needed for supply and demand to add up. As long as the market concept we have today is intact, there will be different production technologies in the market, with different marginal costs, resulting in a merit order curve suggesting increased probability of large price jumps when the market is working near its capacity limit, the same argument holds for price volatility.

The results in paper III can also provide some intuition about further European electricity market integration, in that the change toward more thermal power in the Nord Pool area is similar to what is expected from further European market integration. Further European integration would result in a production structure with relatively more thermal power, compared to the current Swedish structure, which could increase Swedish electric power prices. This can be verified by comparing the production mixture in Sweden for the period studied (1996-2007) to the overall European production mixture. In Sweden approximately five per cent of the electric power is produced using thermal power plants. In 2009 more than 40 per cent of the electric power production in EU-27 came from coal fired plants (www.IEA.com). As such, further market integration with Europe will cause the Swedish mixture to be of relatively more thermal power. Thermal power is relatively more expensive to produce than electric power from hydro and nuclear power plants, and this can, combined with more interconnectors in the future, imply that the marginal unit more often will be the more expensive thermal power, also in Sweden. However, it should also be mentioned that including more intermittent power sources could affect
the outcome. Research results indicate that more wind power in the system can cause average price to decline but volatility to increase (e.g. Elforsk, 2009, Green and Vasilakos, 2012 and Mauritzen, 2013).

Paper IV investigates to what extent shocks in demand and supply for electricity translate into electricity price jumps, and how this process is affected by the prevailing market structure. The main findings from the study are that the prevailing market structure, i.e. on how far the market works from capacity constraints will determine how the demand and supply shocks translate into electricity price jumps. A notable finding of the empirical analysis is that the marginal effects from positive demand and negative supply shocks on the jump probabilities are mostly insignificant and of small magnitude. One interpretation of this is that the market is working relatively efficiently in handling these types of shocks. It is also concluded that from a Nordic perspective, market integration seems to have worked well in terms of creating a market more capable of handling external shocks, especially in periods when the market has not been working close to capacity constraints.

To make an overall conclusions from the four papers in this thesis there are two things that should be highlighted. First, the pricing of electric power, i.e. marginal cost pricing, seems to have created an electric power market that is competitive and also is beneficial for consumer welfare. Secondly, enlarging electric power markets seems to have several good implications. Larger markets works to; i) prevent market power abuse, ii) reduce the probability for sudden price jumps, iii) create better conditions for markets to handle external shocks to supply and demand. However, to some extent all this is conditional on interconnections between different areas.

All in all, from the general findings in this thesis there are some overall policy conclusions to be made.

- First, the pricing of electric power at Nord Pool seems to be close to marginal cost pricing. As such, pricing at Nord Pool seems to be close to that in a competitive market, and there is no need to intervene in the market for this reason. Nevertheless, policy makers should be careful in monitoring future developments in the electric power market. One reason for this is that introduction of more intermittent renewable energy such as wind- and solar power will have an impact on the electric power market.

- Second, the change of pricing method following with the deregulation has been beneficial for consumer welfare. As such, there is no need for policy makers to intervene in the electric power market's pricing principle to protect customers against high prices. If policy makers are to lower the customers electricity price they
should concentrate on other factors contributing to the price the customer faces, i.e. taxes and environmental fees, or work towards making customers more price sensitive and more active in their decisions when to consume the electricity.

- Third, enlarging electric power markets has reduced the probability of sudden price jumps. Price jumps are in most circumstances not beneficial for customers as they are often risk averse and prefer their price to be stable.

- Fourth, enlarging electric power markets seems to have created better conditions for the market to handle external shocks to supply and demand than separate national markets previously did. As this is beneficial for risk averse market participants, it is another reason for policy makers to continue the work towards an internal European market for electricity.

- Fifth. The knowledge that how close to the capacity constraint the market is working will affect the volatility and also how large price spikes can be has to be communicated to policy makers. It is then up to them to decide how to handle the matter. If policy makers are to lower the price spikes one solution is to build more capacity, another is to get the demand side more active and lower their consumption when price spikes occur.

- Last, but not least. In order for electricity market reforms and market integration to achieve their goals, the policy makers need to address that electricity market reforms has to be supplemented with enough transmission capacity. With sufficient transmission capacities between areas the relevant market area expands and the reforms have a better chance to succeed.

4 Future research

The rapid progress of the electricity market, both in Sweden and in Europe, implies that new research questions emerge, but also that previously interesting questions suddenly become obsolete. This demands that the research keep up with the changes. Old research results are not necessarily true when market conditions change and the decision makers need all the help they can get to get it right.

The research presented in this thesis give answers to some questions, but also raises new questions. In the light of the scope of this thesis it is in three particular areas that I would like to highlight regarding future research. First, regarding analyses of market power abuse the progress towards more intermittent electric power production sources need to be addressed even more. This is done by e.g. Mauritzen (2010) and Twomney and Neuhoff (2010). However, more research is needed in the light of intermittent electric
power growing fast. More research in the subject is also needed in the setting of the Nordic area where the intermittent production is incorporated in a hydro dominated power system.

Secondly, the effect of a more elastic demand side is another interesting subject for future research. Sweden could be an interesting case as the households from 1 October, 2012 can get hourly reading of their electricity consumption. This may have several interesting implications worth studying. For example how the price elasticity is affected and if the Nord Pool prices are affected by that. And if the price elasticity increases, what are the effects for the market functioning? Does it affect utilization of market power in electric power markets as theory foresees it should?

Thirdly, regarding the electric power price dynamics an elaboration on how different variables contribute to price spikes and volatility should be interesting, and also a natural continuation on paper IV. Also, using more high frequent data as well as accounting for possible congestion in the transmission system should be interesting to incorporate in the analysis.

References


Introduction and summary


Elforsk 09:102: “Effects of Large Scale Wind Capacities in Sweden”.


