NORGES HANDELSHØYSKOLE
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Price Effects of CO_2-quotas on the Nordic Electricity Market

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NORGES HANDELSHØYSKOLE

Summary

The aim of the thesis is to examine the electricity market and the introduction of CO_2-quotas. In order to perform this study, the text is divided into five main sections. The introductory section presents several assumptions that make it possible to model the quotas as an imposed unit tax on the producers of electricity. Section two consists of a thorough competition analysis. Section three examines the distinctive price formation in the market for generation of electricity, while section four presents empirical data from the early stages of the quota regime. This part of the thesis also uses the basis formed earlier in order to predict the price effects of the introduction of CO2-allowances. The concluding remarks summarize the findings, which show that the price for consumers will increase.

Preface

The work on this thesis has been challenging. Several people have offered priceless help. First and foremost, I want to thank my advisor, Kåre P. Hagen. He has been available for advice at all times, and the quality of his help is unquestionable. I can honestly say that it has been an absolute pleasure working with Professor Kåre P. Hagen. Furthermore, I owe a great deal of gratitude to my brilliant mother, Elna A. Gjesdal. She found time amongst all her other obligations to help me with my work. I would also like to thank my good friend, Tarjei Holmefjord. He has spent nightshifts reading through the final draft of this thesis. My father, Frøystein Gjesdal, also deserves to be mentioned here. He is always helpful when asked for advice, which is greatly appreciated. My partner in the school library, Stian M. Anke-Hansen, has provided me with insight into the world of computers. Finally, I would like to thank my girlfriend, Hanne Digranes. She is the one who has to put up with me when frustration becomes overwhelming.

I chose the Nordic electricity market, and the introduction of quotas, as the theme for my master thesis. I find this market quite fascinating. The market has evolved in recent years, and it has become highly relevant with the emergence of the fight against climate change.
The goal of the thesis is formulated in the title. A personal goal in the work with this thesis is to obtain a greater understanding of the complex electricity market.

Because of the time frame, the scope of this work is perhaps limited. It has been tempting to study some of the aspects more thoroughly. Nevertheless, I hope that the thesis offer relevant discussions and interesting results. The study has been performed to the best of my ability, and all the views presented here are my own.

Bergen, 06.20.2008
Jon Peder Gjesdal

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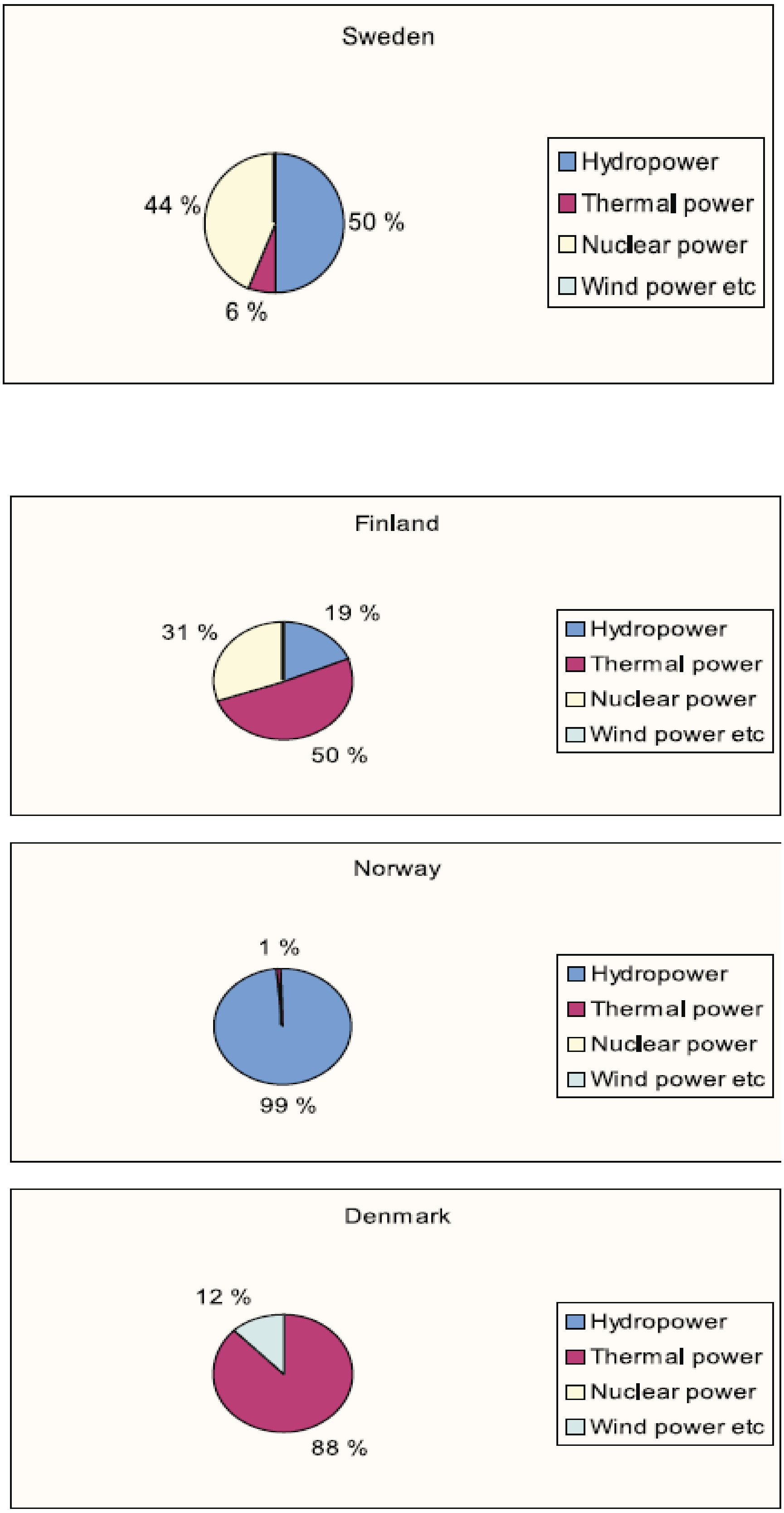
1.0 Introduction

The Nordic market for electricity is rather complex and has developed a great deal in recent years. In 1990 the Energy Act started the deregulation of the electricity sector. The structure of the markets went from closed national markets to an integrated Nordic market. In 1996 Nord Pool was introduced. Nord Pool became the first multinational exchange for trade of electricity in the world. This exchange organizes buying and selling of electricity by receiving orders of supply and demand, and creating a *system-price* by matching these. The system-price defines, at a given point in time, the price of transactions in the market for electricity the following day. This price will be referred to as the *spot-price* from now on.

The production of the electricity traded on the exchange originates from several different production technologies (See figure 1.1). Roughly 55% of the electricity is generated from hydropower, while Nuclear power provides about 24% and thermal power 20%. Wind power also contributes, mostly from Denmark. These production technologies differ in many aspects, for example with regards to flexibility, emission of greenhouse gases and production costs.

This diversity in production is a key to understanding the electricity market, and will be important during the work with this thesis. Figure 1.1 underlines the unique position that Norway holds in the Nordic market for generation of electricity.

Figure 1.1: Distribution of production technologies.



Source: KT, “A powerful competition Policy, 2003

1.1 Motivation and Outline

The purpose of this thesis is to uncover what effects the introduction of quotas for emission of CO_2 has on the prices in the Nordic electricity market. As previously mentioned, this market is somewhat complex and plays an important role regarding emissions of climate gases and the problems associated with those. The goal for this thesis is to obtain an understanding of this interesting market, in addition to investigating the consequences of the quotas.

In response to the Koyoto-agreement the EU introduced the ETS, the European trading scheme. Quotas for emission of CO_2 were allocated to actors based on historical emissions. The general idea of the system is to exploit market mechanisms to reduce the emission of gases dangerous to the environment. In order for this to work, the allocation needs to create a shortage of quotas. Then the quotas will attain a value in the market. By this, emission of CO_2 will imply a cost for actors in the market. The EU is hoping that the introduction of the ETS will help to reduce future emission. This introduction of quotas will have a significant impact on the market for electricity. Generation of thermal electric power is the largest contributor to emission of greenhouse gases. This gives hold to my strong motivation to examine the electricity market in general, as well as the specifics of the quota system.

The first period of the ETS finished at the end of 2007. In retrospect, this first part of the project cannot be considered a complete success. The allocation of the quotas was too generous, and as a result of that the price of the quotas at the end of the period was close to zero. Nevertheless, a market infrastructure was established during the trial period. The volume of trade was also increasing by the end of the first phase. These are indeed positive signs for the future development of the quota-system. The second part of the ETS was launched at the start of 2008. The distribution of quotas is now by means of auctioning. This new approach to allocation will hopefully lead to increased values of the quotas and an effective distribution, and thereby a greater chance of the project reaching its objective. The performance of the ETS is being monitored by public officials around the world, and its success will increase the chances of establishing a global system in the fight against climate change. This further underlines the motivation for this thesis.

The introduction of this thesis will continue with the presentation of the effects of the quotas in an ideal world of perfect competition. Section two will consist of a thorough competitive analysis of the Nordic electricity market. An overview of the competitive environment will provide a useful basis in order to examine the effects of the quotas. Section three will elaborate in detail on the price setting mechanisms. A focal point here will be to establish the price effects of the CO_2-allowances on the Nordic electricity price. The Nordic price is formed on the basis of a quite complex set of factors. These will be discussed in section three. Section four will introduce the quotas. Firstly, a descriptive part concerning the experiences thus far will be presented, as well as data on prices and volumes in the newly established market for emission trading. The final part of the section will use the results from previous sections in order to determine the price effects. Section five will present the conclusions based on the discussion in the previous sections.

1.2 The Impact of CO_2-quotas in an Ideal World of Perfect Competition

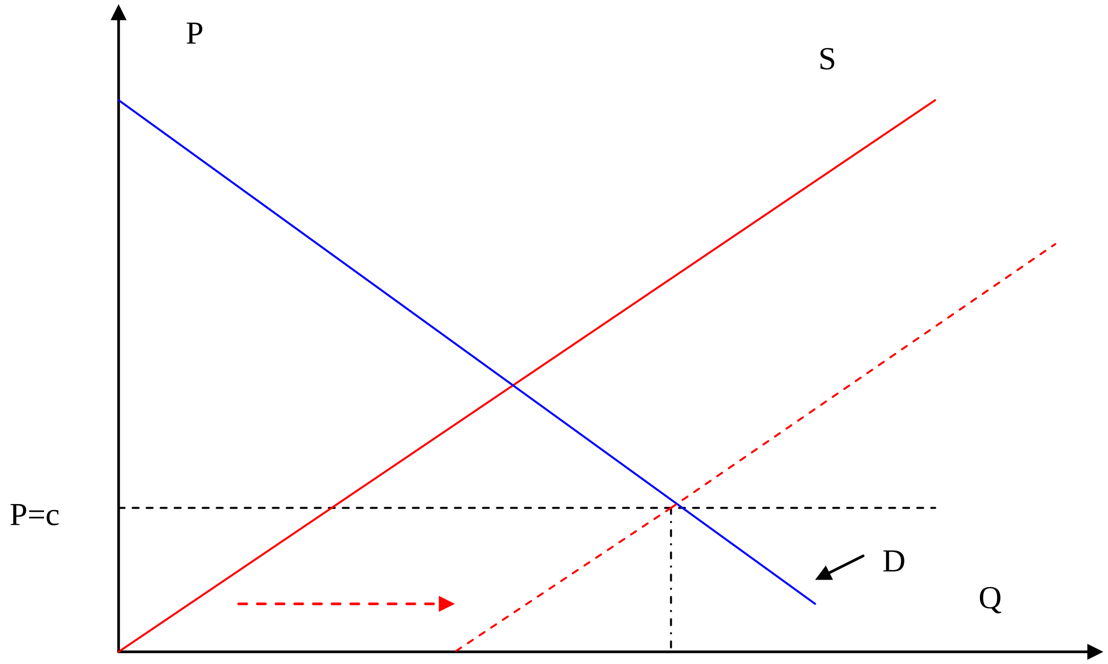
The Nordic electricity market has several distinctive characteristics that effect the competitive environment. Different production technologies, capacity constraints in the cross-border transmission grid and market concentration are all factors that make the competitive situation illusive. These topics will be discussed thoroughly later in the thesis in order to form a basis for further understanding the effects of the quotas. Even though the Nordic market for electricity generation hardly resembles a market with perfect competition, it is useful as a benchmark to study our problem in the stylized world of perfect competition.

Perfect competition is rarely or never observed in its purest form; however it is often a useful approximation. Several requirements need to be fulfilled in order for a market to be perfectly competitive. Firstly the goods produced in the market must be homogeneous or perfect substitutes. Secondly, consumers must not be restrained by switching costs. This means that consumers can switch to another supplier without encountering costs in the form of money, time consumption or other transaction costs. A third point regarding customer power and the demand side of the market is perfect information. If consumers are able to exploit the absence of switching costs to respond to a higher price from one producer, the market must be transparent. The producers as well as the consumers need to have access to all information regarding price changes. If these conditions are fulfilled, producers cannot raise prices without losing customers. Also, suppliers and buyers must take the market price as given.

Perfect competition means absence of market power. One way of defining market power is that a player in the market can raise the price level by a given interval without losing market shares. Market power is an obstacle to competition. In addition free price formation and profit-maximizing actors in the market will enhance perfect competition. Profit maximizing actors is a basic assumption in economics, and free price formation demands the absence of government regulation. The last condition worth noting on the supply side is the lack of entry barriers. Incumbents in a market will be disciplined by the fact that new entrants can establish themselves if the business is profitable.

Consequently there are strict conditions that need to be fulfilled in order to obtain perfect competition in a market. These factors enhance the competitive environment and will lead to tougher price competition. The actors in the market can not raise its price without losing customers. When considering a situation with only two players in a market, both competitors will have an incentive to cut their prices marginally (epsilon) below the market price, and thereby capturing the whole market. Game theory illustrates these mechanisms. Based on the assumption that all competitors are aware of and have the same incentives, the only long term equilibrium is price equal to marginal cost.

Figure 1.2: Bertrand Paradox



$$\pi_1 = \begin{cases} (P_1 - c)D(P_1) & if \quad P_1 < P_2 \\ \dfrac{(P_1 - c)D(P_1)}{2} & if \quad P_1 = P_2 \\ 0 & if \quad P_1 > P_2 \end{cases}$$

Figure 1.2 shows the only long-run equilibrium in a market with perfect competition and with equal and constant marginal costs on the supply side. In a Nash-equilibrium the players do not regret their choice given their competitor's actions. There is no profit for producers and the quantity covers demand in a satisfactory way. This perfect competition equilibrium maximizes economic welfare. The dynamics of the game mechanisms that lead to the solution of the tough price competition are shown formally below the figure.

We rarely observe this type of situation because of the strict conditions that were discussed above. However, for the purpose of this thesis it is useful to study the effects of the quotas in this hypothetical scenario. The introduction of CO_2-quotas can be viewed as a tax imposed on production of electricity which leads to emission of climate gases. The producers thus face an externally imposed cost tied to their production. The size of this cost will depend on the emission level tied to the production, as well as the market price of the $C0_2$-allowances. The quotas are analogous to a unit tax. There is one vital assumption worth noting in order to claim that the quotas can be modeled as a unit tax. The quantity of emission needs to be constant per unit of output (electricity). This is indeed true for generation of electricity. The emission level is a linear function of production.

The emission of climate gases now includes a cost for producers, and thereby raises the marginal cost of production. This cost increase can come as a direct effect when actors purchase quotas at market price, or as an opportunity cost as the quotas can be sold in the market. The latter implies that there is a cost involved even though a hypothetical producer is allocated quotas that covers its need free of charge. Another implication of the opportunity cost is that it enables us to model the price effects of the quotas with a model of a tax imposed on producers. This model will be presented below, but firstly two different alternatives for market intervention regarding externalities will be given attention.

Problems in the form of externalities arise when the activities of individual market participants affect surroundings which are of public interest in a negative way. The incentives of individual actors differ from the interests of the general public. Emission of climate gases is an example of this. There is a need for market intervention in order to handle this kind of problem. When faced with emissions, two different approaches are usually considered: One is imposing direct taxes on emission. The other is a quota based approach, which is the relevant scenario in this thesis. It is argued above that the price effects of both alternatives can be modeled the same way. Nevertheless, it is useful to pinpoint the differences between direct taxation and allocation of allowances.

There are often two main differences brought forward concerning quotas versus direct taxation. Allocation of quotas that are non-tradable leads to an ineffective distribution. Officials who impose the quotas do not have information regarding the cleaning costs, and the market participants do not have incentives to reveal this information. The main problem with taxation is that it is impossible to control the level of emissions accurately. The ineffectiveness of the quota approach can be solved by making the quotas tradable. This has been done with the ETS. This implies that the cost effectiveness is not an argument favoring direct taxation. The discussion is thereby dependent on the trade-off between the need of control of emission levels and the incentives to invest in cleaning technology given to market participants. Direct taxation will give a larger incentive to invest in cleaning technologies. The incentive to invest in cleaning technology for market participants, is solely dependent on the cost imposed from emission of climate gases. This cost is represented by the size of the tax, or in the quota scenario, by the market price of the quotas. When market players invest in cleaning technology, the demand for quotas will be reduced and the optimal level of emission will be higher with a quota-based system. When producers are faced with an imposed tax, the cost of emission is given by the size of the tax. This is decided by the government, in other words externally, and there will not be an equilibrium effect increasing the optimal level of emission:

Figure1.3:

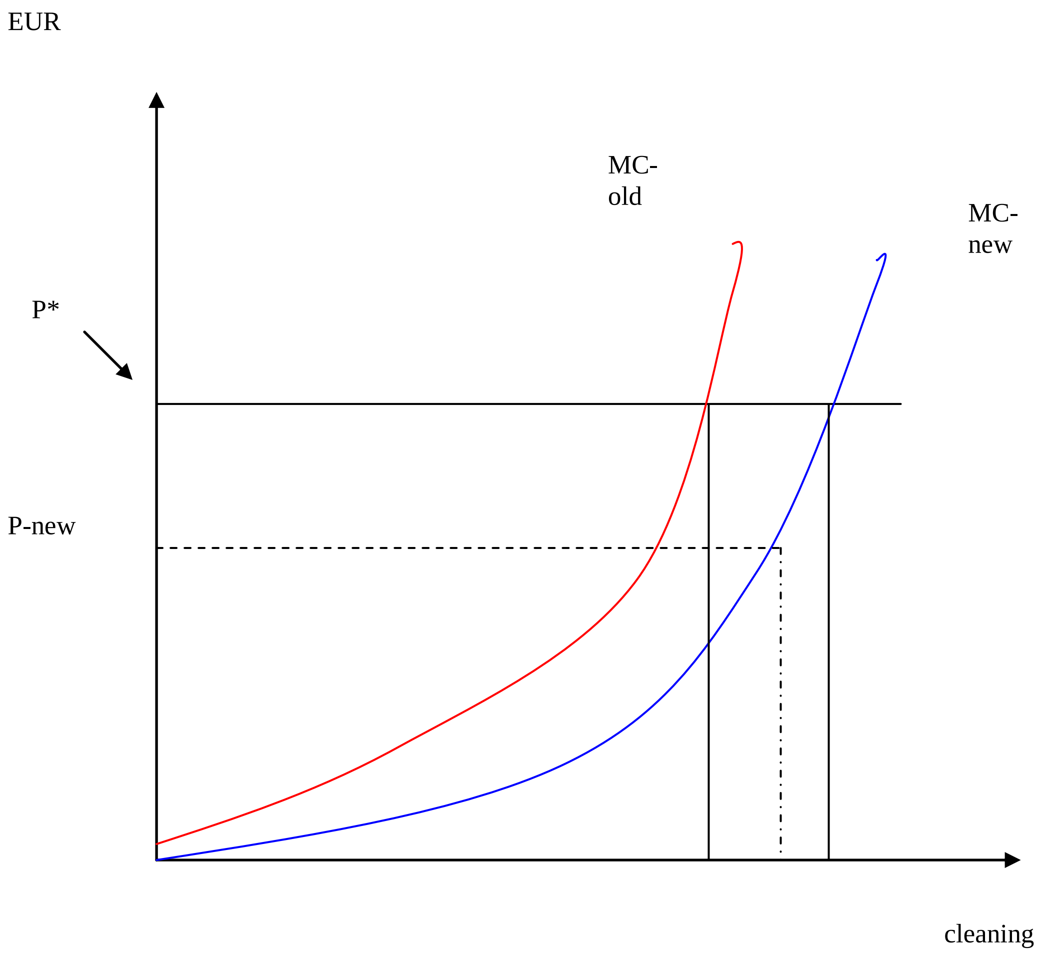


Figure 1.3 is meant to illustrate the reasoning above. The profit from investing in cleaning technology is given by the difference of the old and the new marginal cleaning cost curves. For the quotas there will be an equilibrium price-effect represented by the dashed lines. The value of the quotas will decrease because of reduced demand for quotas. As a result there will be less cleaning and more emission compared to the tax solution.

The view of this thesis is that for a given cleaning technology, a quota-based approach to the emission problem is optimal. It is vital that government officials can monitor the emission level for the ETS to be credible. The trading scheme is based on clear-cut quantitative goals as formulated in the *Koyoto- agreement*, and a quota-system is efficient in fulfilling these requirements. Hence, the two different tools for fighting climate changes can be modeled the same way (See discussion above). The price effect of a government-imposed tax is a well known problem in micro-economics, and is presented below:

Figure 1.4: Tax imposed on production

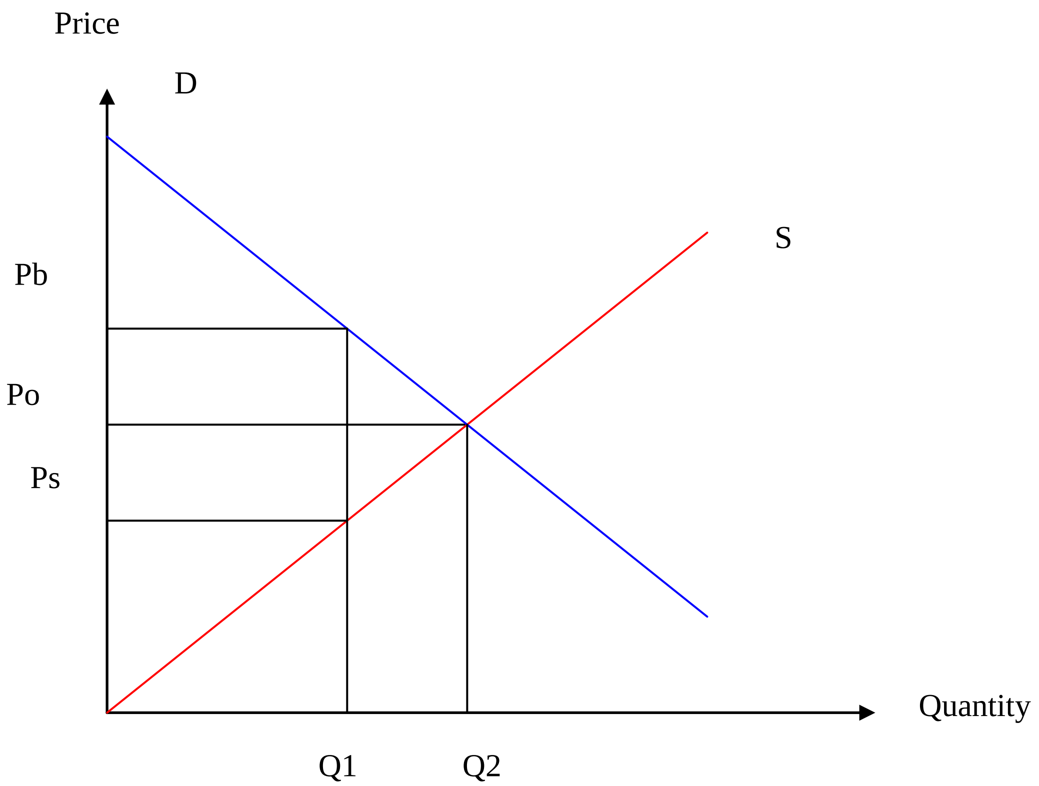


Figure 1.4 shows the theoretical effects from quotas from this simple approach to the problem. The producers and the consumers will split the downside effect of the increase in production costs and there will be a higher price and a lower quantity of electricity in the market. For simplicity, the figure is meant to be symmetrical around P_0. The simple figure is not meant to explain the exact size of the effects of the tax. This will depend on elasticity of supply and demand. The interval between the new price for the suppliers (Ps) and the new price for the buyers (Pb), is equal to the tax imposed on the producers. The loss of consumer surplus is given by the sum of the top rectangle and triangle. Accordingly, the loss of producer surplus is the bottom rectangle plus triangle. The deadweight loss is graphically illustrated by the two triangles. The deadweight loss is derived by the consumer and producer surplus, less the increased government income, which is the sum of the two rectangles. This result is interesting in itself, but for the purpose of this thesis it is worth noting that these results do not consider the elasticity of demand. The elasticity is important to examine in order to forecast to what extent the producers succeed in transferring the burden of the tax on to the consumers. If the elasticity of demand for electricity is inelastic, which is not far from the truth for the electricity market, at least in the short run, we will probably observe a greater increase in price and a more stable level of quantity. The slope and structure of the supply-curve will also affect the results presented in the figure.

In equilibrium:

$$Q^s(p-t) = Q^d(p)$$

(1.2.1)

We are interested in the change in consumer price in response to a change in tax imposed:

$$Q^S{}'\left(\frac{dp}{dt}-1\right) = Q^D{}'(p)\frac{dp}{dt} \qquad \textbf{(1.2.2)}$$

Solving for the change in consumer price with respect to change in tax imposed yields:

$$Q^{S'}\frac{dp}{dt} - Q^{S'} = Q^{D'}\frac{dp}{dt}$$

$$(Q^{S'} - Q^{D'})\frac{dp}{dt} = Q^{S'}$$

$$\frac{dp}{dt} = \frac{Q^{S'}}{Q^{S'} - Q^{D'}} \geq 0 \qquad \textbf{(1.2.3)}$$

$$\frac{dp}{dt} = 0 \; for Q^{S'} = 0$$

$$\frac{dp}{dt} = 1 \; for Q^{D'} = 0$$

The two latter expressions show the extreme scenarios. When either supply or demand is completely inelastic we have a horizontal supply curve or a vertical demand curve. An inelastic supply implies that producers carry the whole burden of the tax. Conversely, an inelastic demand causes the burden to be absorbed by the consumers. The figure above is meant to illustrate these mechanisms in a neutral way. In other words, it is not meant to illustrate the characteristics of the electricity market in any way. From the last equation we can derive the theoretical expression for this scenario:

$$\frac{dp}{dt} = \frac{1}{1 - \frac{Q^{D'}}{Q^{S'}}} \qquad \textbf{(1.2.4)}$$

Expression **(1.2.4)** indicates that when assuming supply and demand is equally elastic, the derivative of the consumer price with respect to the tax imposed equals 0.5. This implies that the burden of the tax is evenly shared between consumers and producers.

The above paragraphs indicate that the characteristics of the electricity market concerning elasticity are important. Discussions regarding the supply and demand of the electricity sector will be elaborated in the next section. The lesson learned from this simplified example is perhaps limited, but we can draw the conclusion that producers which face an externally imposed cost will try to make the consumers carry the load. To what extent they succeed will depend on the structure and competitive environment of the market. The next section will discuss this in further detail, but firstly a final preliminary factor needs to be addressed.

A model which describes the future structure of the electricity market has been established. An obstacle is to translate the value of the quotas, which is denominated in Euro/metric ton, to Euro/MWh. The carbon intensity of electricity production is the variable we are looking for. We will use coal based production as the relevant benchmark. Støyva (2005)[1] reports that the emission from a coal based power plant emits 0.321 tons CO_2 in the production of one MWh of electricity. This presupposes 100% effect of the power plant, which will never be the case. The efficiency of the power plants varies surprisingly. Støyva reports that in 2005 Danish thermal production had an average efficiency of roughly 65 %, while Germany could only manage around 35%. This efficiency measure says how much output the power plants generate for one unit of input (Coal). The carbon intensity is derived by dividing the emission level of a 100% power plant with the relevant estimate of efficiency for a representative coal based power plant. For the purpose of this thesis the efficient Danish plants will be an appropriate approximation. The reason for this assumption is that with the emergence of the quota-regime, the least efficient production facilities will probably become obsolete. It will be too costly to maintain production with unnecessary high emission levels. Therefore, the estimate of the carbon intensity of electricity production in this thesis is

$$(0.321/0.65)\text{t/MWh} = 0.49\text{t/MWh}$$

This would mean that with 100% transfer of the quota price to the electricity price, a quota-price of 25 EUR/t would imply an increase of roughly 12 EUR/MWh in the electricity price. Before we can say anything about the price effects of the quotas, the competitive environment must be examined.

[1] Støyva G, (2005), *"CO_2-kvotenes innvirkning på den Nordiske kraftprisen",*

2.0 Competition Analysis of the Nordic Market for Electricity

In order to draw any further conclusion from the effects of the CO_2-quotas on the electricity market, one needs to examine the distinctive characteristics of this market. The purpose of this section is to clarify to what extent the competition is well functioning. The a priori idea is that if the market has features that resemble perfect competition, the quotas have a greater chance of reaching its objective. If market power is observed in the market, the producers have greater means to make the consumers carry the extra cost of the quotas. An actor which possesses market power can raise its price without losing market shares. This scenario will lead to higher prices in the electricity market, but will not necessarily lead to a significant shift in production. The objective of the quota- system is of course to twist the production of electricity towards production technologies that lead to less emission of climate gases. It would also be beneficial if the introduction of the quotas causes a decrease in the consumption of electricity. However, this scenario is considered to be less likely, as it is difficult to imagine that the public is willing to reduce its consumption significantly. This will depend on the elasticity of demand.

With the basic assumption that competition-hindering features will have a negative effect on the objective of the quota-system, this section will shed light on the competitive environment of the Nordic electricity sector.

2.1 Relevant Product Market

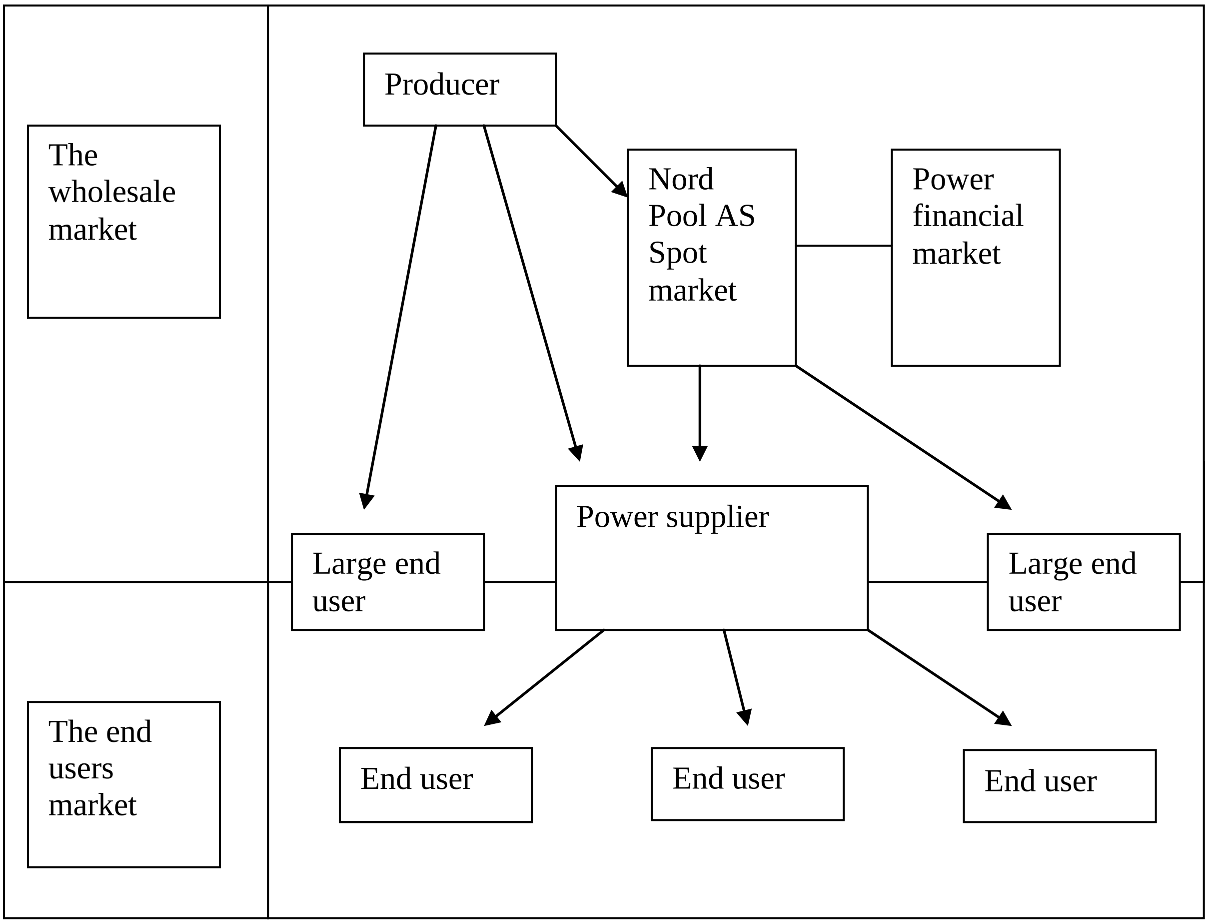
Defining the relevant product market is a necessary first step in order to perform a competition analysis. When defining this market, one is interested in the smallest possible market in which a hypothetical monopolist can exploit its dominant position. The European

Commision has defined this market as the sale of electricity through high-voltage network.[2] There are no close substitutes for electricity today. The demand is inelastic, especially in the short run. Consumers are not able to monitor price changes from hour to hour, and they do not have many alternative sources of energy. Based on these arguments we can establish that wholesale of electricity is a separate product market. The producers in the wholesale market could increase prices without consumers switching to alternative energy sources, at least in the short run.

The wholesale market is thus defined as a separate market, but we need to examine whether this is the smallest possible relevant market. As noted in the introduction, the wholesale market is structured both as bilateral contacts as well as trade on the Nord Pool exchange. Producers of electricity sell their product to large end-users and power suppliers through both these outlets. Figure 2 gives an overview of the distinctive structure of the market:

[2] The Norwegian Competition Authorities, (2003),*"A Powerful Competition Policy"*

Figure 2.1: The structuring of transactions in the Nordic electricity market.



Source: Based on a diagram from KT (2003)

The bilateral and Nord Pool markets are separate markets if an actor can raise the price within one of these markets without customers switching to the other arena. This question is somewhat difficult to answer due to the lack of transparency in the bilateral market. There is a large diversity of contracts in the bilateral market. The time frame of the contracts in the bilateral market will also play a role in the consideration of this market. The longer the horizon of the contracts, naturally, the more difficult it would be to switch to the spot market. Nevertheless, an important feature of these contracts is that they are usually structured with the Nord Pool spot price as a basis for price formation. In addition, the spot price is available for all parties to see. Both these factors will make it difficult for a hypothetical monopolist to raise prices without losing profit from customers switching market place. When following this reasoning, the bilateral market and the spot market belong in the same relevant product market.

There are thus arguments in favor of considering the bilateral and spot markets as belonging to the same relevant market. This view is shared by the Norwegian and Danish competition authorities. When considering the case of Statkraft´s acquisition of Agder Energi and Trondheim Energiverk, the Norwegian competition authority concluded that the bilateral and the spot market were close substitutes and therefore belonged to the same market. The Danish authorities came to the same conclusion when dealing with the abuse of dominant position by two market participants in Denmark[3]

There are reasonable arguments in favor of accepting the bilateral and the spot markets as belonging to the same relevant market. This approach will be employed in this thesis.

2.2 Relevant Geographic Market

In the sub-section above we found the relevant product market to be the wholesale market for sale of electricity. The next step in the analysis is to determine the relevant geographic market. Before the deregulation of the electricity sector, the Nordic markets were closed and strictly national. It would be tempting to claim that the Nordic market after the deregulation is a totally integrated market, and thus that the relevant geographic market is the Nordic countries. However, the solution to this problem does not present itself easily.

Even though water can be stored, the product of electricity is impossible to store. It has to be consumed the moment it is delivered. This time dimension is important because it influences the extent of the geographic market. There are at times constraints in transmission capacity between different regions in the Nordic market. These constraints are often referred to as

[3] KT (2003)

“bottlenecks”. These bottlenecks will at certain hours divide the Nordic region into several different price areas, or different relevant geographic markets. This special feature of the electricity sector offers challenges when studying the market from a competition point of view. Usually, competition authorities require geographic markets to be stable over time in order to establish abuse of a dominant position. Because of the congested transmission grid, this is not possible in the market for generation of electricity. Nevertheless, it is important to establish the smallest possible area where a hypothetical monopolist can raise its price without losing market shares. The different price areas which arise in times of congestion, are clearly markets where such a monopolist can abuse a dominant position. This is the case both in surplus areas and in deficit areas. In surplus areas the producers are net exporters, and a dominant actor can withhold production to maintain the price in the area at an acceptable level. In a deficit area, where imports are limited, the leading market participant can raise its price without losing market shares to surrounding price areas.

These price areas can often be observed directly from Nord Pool. In these cases, the price areas are treated as different El-spot areas on the Nord Pool exchange. When the price areas cannot be observed on the exchange, the price areas are dealt with by the means of *counter-trade*. This implies that the Nordic TSO’s sell and buy electricity on both sides of the bottleneck in order to reduce the effects of the congestion. This is often done in order to complete the announced trade on Nord Pool in line with the 36-hour guarantee[4]

The problem when trying to define the relevant market arises because of the uncertainty related to the time horizon of the congested transmission grid. Copenhagen Economics (2002) performed a study where they quantified the different price areas in the Nordic electricity sector in 2001.

The results obtained by Copenhagen Economics[5] (2002) show that the market is divided into different price areas about 50% of the time. These figures will vary from year to year due to large variations in precipitation. The relevant geographic market was, for example, smaller than the Nordic region about 65% of the time in 2002. As we can see, it is difficult or impossible to accurately define the relevant geographic market. Before finishing this discussion concerning the geographic markets, it is worth noting that the Nordic transmission

[4] Energinet.dk 07.08.07

[5] The Norwegian Competition Authorities, (2003),*”A Powerful Competition Policy”*

grid is connected to continental Europe via Denmark. One could argue that the relevant market is even larger than the Nordic region. Several studies have shown that this is not the case. The approach that will be used in the further elaboration of this thesis is that the relevant market is smaller than the Nordic region.

2.3 Market Concentration

The previous sub-sections have formed a basis needed to embark on an analysis of market concentration and possible dominant positions in the market. As noted above, the relevant product market is considered to be wholesale of electricity, and the relevant geographic market is smaller than the Nordic region. The smallest markets are defined. The task ahead consists of trying to establish whether any actors within these markets have a dominant position enabling them to abuse market power. With our assumptions of rational actors, a dominant position will automatically lead to abuse of this position.

The process of estimating market concentration is often relatively straight forward. Market shares are the basis of the calculation. The total market shares are accumulated and compared to threshold values in order to determine whether the market is unconcentrated, moderately concentrated or highly concentrated. The picture becomes somewhat more complicated when applying this method to the Nordic electricity market. There are several factors which add to the difficulty of calculating market concentration. Firstly, the ownership of power plants is often structured as joint ownership. Market shares in the electricity sector are usually calculated as each actor’s share of production or installed capacity. When two or more production companies have shares in the same plant, it is difficult to estimate market shares. The solution is often to determine the owner who has control over the plant and consider that company to fully own the power plant. In addition to joint ownership, there is a great deal of cross ownership in the Nordic market for generation of electricity. Cross ownership can be either direct or indirect. The relationship is direct if one company owns shares in another company competing in the same market. Indirect ownership occurs when a company owns shares in a competitor, which in turn owns part of a third party.

The ownership structure in the Nordic market makes the calculation slightly complicated, but the Norwegian competition authorities (KT) performed a thorough study on this topic in 2003. In addition to this report, SNF published an article on commission from KT about ownership relations and cooperation in the Norwegian Power market[6]. I will present the results on market concentration from these two publications in this sub-section.

2.3.1 The Herfindahl index

The most commonly used tool for quantifying market concentration is the Herfindahl index (HHI). The model is simple in its mathematical form, and is defined by the sum of the squared market shares of all market participants:

$$HHI \equiv \sum_{i}^{n} (\alpha_i)^2$$

Since the terms in the equation are squared, the model emphasizes the larger market shares. The HHI will be noted in whole numbers, with market shares presented as percentage sizes. A market with an HHI of less than 1000 is considered to be unconcentrated. A moderately concentrated market will have an HHI roughly between 1000 and 1800, while a highly concentrated market is above 1800. The companies are treated as strictly independent when computing the HHI. For the electricity sector this can lead to inaccuracy. This market is characterized by a great deal of cross ownership. The companies may therefore have fewer incentives to compete. If one actor in the market raises its price, the loss of profit from lower sales will be partly eliminated by a corresponding increase in sales for a competitor, in which the first company has ownership interests. This effect is referred to as the *incentive-effect.* Another effect caused by the high degree of cross-ownership is the *control effect*. If one company has direct control over a competitor in the market, it can coordinate the actions of

[6] Singh B. and Skjeret F. , (2006), "*Ownership Relations and Cooperation in the Norwegian Power Market",* SNF

the two actors in the market, and thereby maximize its profit. This will naturally hinder competition.

KT (2003) calculated the HHI and adjusted for both the effects described above.
The results are presented in this table:

Table 2.1

	HHI	HHI	HHI
Finland	1766	2037	3005
Norway	1634	1980	3325
Sweden	2893	2923	2988
Denmark	4844	4844	4844
The Nordic Market	892	989	1138

Source: KT (2003)

The effects of cross-ownership in the electricity sector can be clearly observed from the results presented in the table 2.1. The unadjusted HHI shows the markets to be moderately concentrated, with the exception of Sweden and Denmark. The HHI adjusted for the *incentives-effect* as well as the *control-effect* tells another story. All the national markets are now well above the threshold for being highly concentrated.

In Norway the government-owned Statkraft has a dominant position. KT estimated their annual average production capacity to be 34.7 TWH, and KT also found that it had an installed capacity of 8356 MW. This would imply a market share of installed capacity to exceed 40%. This number is adjusted for direct ownership of other market participants. The calculation of indirect ownership would increase this figure further.

The extent of cross-ownership is smaller between countries in the Nordic region. Therefore the increase in the adjusted HHI is not as dramatic as for the national markets. The discussion above regarding the relevant markets of the Nordic electricity sector leads to the conclusion that the relevant markets are smaller than the whole Nordic region. In fact, we found that the relevant markets are often smaller than the national markets. The most interesting result is the observation of the highly concentrated national markets.

Based on the discussion concerning the relevant markets and the study on market concentration performed by KT, we have established that there is an environment where market participants can exploit a dominant position. In the Norwegian market this player would be Statkraft. Stakraft will naturally claim that as a government-owned company, it has no incentive to abuse a strong position in the Norwegian market. Nevertheless, as a commercial actor, it has a basic motive to maximize their profit.

It is not the purpose of this thesis to explore the grey areas of optimizing production in contrast to the abuse of a dominant position. Rather, the goal of this work is to uncover the effects of the CO_2-quotas on prices and production in the market for generation of electricity. With this in mind, establishing a highly concentrated market is relevant. In the first section we studied the effect of the quotas in the hypothetical scenario of perfect competition. A highly concentrated market entails that the conditions for free competition are far from fulfilled. This will have a significant effect on the discussion of the quotas. The definition of abuse of market power that we have used before, is that a company will withhold production in order to maintain a high price. In other words, the company will try to get as close as possible to the monopoly solution. A market participant with market power can do this without losing profit due to the loss of market shares. The introduction of CO_2-quotas can be viewed as a government-imposed tax on the producers of electricity. In the case of perfect competition the producers and consumers would to a varying degree, share the burden of this tax. The scenario with imperfect competition is far more complex. An a priori discussion about the price-effects of quotas is difficult. We have established that the market is concentrated and that Statkraft enjoys a dominant position in the Norwegian sector. That does not necessarily mean that they can exploit their market power. This question partly depends on the demand side of the market. The next sub-section will draw attention to this aspect. Furthermore the role of price-setter is needed in order to abuse a dominant position. In dry years Norway experiences a power deficit and depends on import of electricity from surrounding areas. In wet years one gets a power surplus and corresponding lower prices compared to other Nordic countries. The congestion of the transmission grid, will provide market actors within one price area the capability of influencing the price within that relevant market. The intuitive approach is that the greater the number of hours that the transmission grid is congested, the more independent the price in a region is of the surrounding areas. This argumentation implies that the price in the Norwegian sector will be less influenced by the introduction of quotas, because the price will be set independently in areas without production based on fossil fuels. In order to elaborate this discussion, the next sub-section will supply an overview of the demand side of the market.

2.4 The Demand Side of the Nordic Electricity Sector

The discussion above found that the national markets in the Nordic region are highly concentrated, and that Statkraft enjoys a dominant position in the Norwegian market. In order to further elaborate our discussion we need to establish a link between market concentration and market power. The elasticity of demand is important when trying to accomplish this.
The Lerner index gives us a simple formal expression for the connection between market concentration and market power:

$\bar{L} \equiv \frac{HHI}{\varepsilon}$ The term epsilon refers to the elasticity of demand.

The rationale behind this simple equation is that a highly concentrated market gives the market participants with large market shares an advantage compared to their competitors. Thus, a large value for HHI in the denominator will increase *the Lerner index*. On the other hand, if a dominant actor in the market faces an elastic demand, its opportunities to exert market power will be limited. Formally, elastic demand will give a flatter demand-curve. Producers can not raise its price significantly without losing profit from the loss of sales. The elasticity of demand is the numerator in the expression above, and will reduce the market power of a dominant actor in a market.

The use of *the Lerner index* is useful in its simplicity, but the whole picture is a bit more complicated. Ability to exert market power will depend of the elasticity of the residual demand. The residual demand curve will determine the optimal allocation in a price-quantity diagram for an individual producer. Residual demand is given by total market demand less the supply given by other producers at a given price level:

$$q_i(p) = D(p) - \sum_{j \neq i} S_j(p) \qquad \textbf{(2.4.1)}$$

The expression for the elasticity of demand:

$$\varepsilon_i = \frac{p}{q_i}\frac{dq_i}{dp} \qquad \textbf{(2.4.2)}$$

There are several factors which influence the residual demand. First of all, the elasticity of the market demand as a whole will affect the residual demand. It is a consensus that the elasticity of demand for electricity is inelastic. Consumers have few, if any, alternative sources of energy. The price awareness is also limited in the short run. Consumers cannot monitor the price fluctuations, and respond to them from hour to hour. This is expected to change slightly in the future when more efficient metering technology is introduced. We can also imagine that substitutes for electricity can make an impact in the future. Nevertheless, the demand must be characterized as inelastic in the present situation.

The level of flexibility in production technologies is another factor affecting the residual demand. As previously noted, there is a wide range of production technologies used in the production of electricity. The flexible production consists of hydro power and condensing power stations. The market participants using these forms of production face a more inelastic residual demand as competitors will have trouble responding to a price increase in the short run, due to inflexible production.

The different production technologies are the origin of another feature that plays a role concerning the elasticity of the residual demand. The diversity in production causes the marginal cost of production to be asymmetric. The producers which have low marginal costs can raise prices without competitors being able to respond.

2.5 Collective Market Power

The purpose of the previous sub-section was to discuss whether the market participants with a dominant position could exert market power. The focus was on the individual firms. The Nordic electricity sector resembles an oligopoly, and therefore the possibility of tacit collusion has to be considered. A market with the characteristics of an oligopoly will be more likely to induce this kind of collective market power the more evenly the market shares are distributed. The reason for this is that the participants in a symmetric market will have similar incentives and retaliation power. The possibility for swift responses reduces the incentive to deviate from a peaceful equilibrium. The level of transparency is important in order to detect deviations quickly. When a market is transparent the players in a market can observe the actions of its competitors and can punish any deviations quickly. Therefore the rational behavior for all market participants is to maintain a peaceful equilibrium.

The Nordic market for generation of electricity is considered to be relatively transparent. Electricity is a homogeneous product, and the price of the product can be monitored on an hourly basis on Nord Pool. The bilateral market is some what less transparent, but as previously noted, the system price from Nord Pool is often the basis from which these contracts are formed. This will reduce the possibility for tacit collusion.

Another factor which reduces the market player’s ability of exerting collective market power is the asymmetric cost structure of the various different production technologies. The producers which face higher marginal production costs cannot respond to a price increase by a competitor. This factor is only relevant when considering the whole Nordic market, since

producers in Norway mainly produce electricity from hydropower. This form of production is characterized by low marginal costs. Hydro power is also flexible, and producers are able to react by altering the production quickly.
Market participants in the Nordic market have opportunities to interact with each other. This is a factor which facilitates tacit collusion. Competitors can meet at Nord Pool and coordinate their production. The power plants are often jointly owned, and this enhances the companies' ability to exchange information.

There are opportunities to interact, but the structure of the Nordic electricity market does not facilitate tacit collusion. The main argument for this view is the asymmetric environment. The market actors with competitive advantage, e.g. producers of hydro power, will have incentives to deviate from a situation with collective market power. The discussion in the previous sub-section regarding the environment for exerting individual market power leads to a different conclusion. The residual demand for electricity has to be considered inelastic. Therefore, it is possible for a producer like Statkraft to exert individual market power.

The conclusion of the preceding analysis is that the Nordic market for generation of electricity is highly concentrated, and that the environment to some extent facilitates the exertion of market power. The introduction of CO_2-quotas will effect the competitive environment in the market. Assuming all things remain equal, the findings above will likely cause the burden of the quotas to be imposed on consumers. The purpose of next sub-section is to quickly summarize and label the results of our findings regarding the competitive environment in the electricity sector.

2.6 Defining the Competitive Structure of the Market

In the first section of this thesis the effects of the introduction of quotas in an ideal world of perfect competition were examined. During that discussion, several strict conditions were presented, and in that regard, price competition was assumed. This theoretical approach is useful, but rarely observable in any market, and certainly not in the Nordic electricity market. We have concluded that the market resembles an oligopoly, and also that there are opportunities to exert market power. In addition, a dominant market participant like *Statkraft* enjoys low marginal costs of production compared to many of its competitors. These factors facilitate the use of a model of an oligopoly with price (Bertrand) competition among players with asymmetric costs of production. This model is useful in understanding price formation, which will be elaborated in the next section. Therefore it will also be the basis for the first part of the discussion concerning the price formation. Nevertheless, this is not the most pertinent definition of the competitive environment. The decisive factor in this regard is the capacity constraints of the production of electricity. The dominant players cannot satisfy the whole demand of the market. This means that competitors most of the time are facing residual demand. The market participants compete with capacity as the decision variable. Therefore, the most accurate description of the competitive structure is an oligopoly with capacity (Cournot) competition.

The next section will go into detail concerning the factors which determine the price in the power sector. The market for electricity is in constant development and several variables are important when trying to understand the mechanisms that set the price for electricity.

3.0 Price-setting Mechanisms

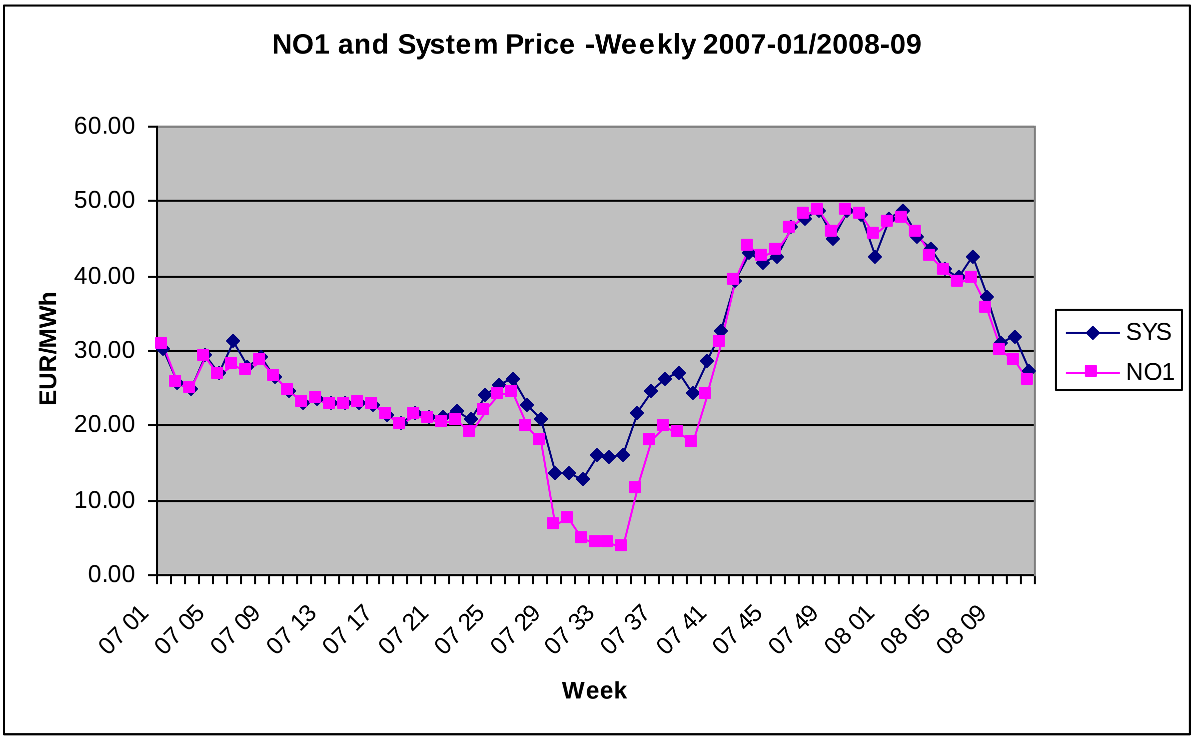
The preceding section shed light on the competitive environment. The conclusion was that the market is characterized by quantity competition, and has the features of an oligopoly. The purpose of this section is to examine the variables that determine the price in the Nordic market for generation of electricity. The market has in recent years developed from a closed national market, to an integrated Nordic market. In the future, one is expected to observe a complete coupling with the market in continental Europe. As a consequence, the Norwegian hydropower producers will not set the price in the market. They will have to take the market price as exogenously given. Nevertheless, the present situation implies that the production of hydropower is often the price setter. How often this is the case is an interesting question when trying to determine the effects of the CO_2-quotas.

In addition to hydro power there are several other variables that have an impact on the price of electricity. These variables will also be studied thoroughly in this section. The most relevant factor is perhaps the marginal cost of production for coal-based electricity production. Studies have shown that this marginal cost sets the price under normal circumstances. By normal circumstances one means that the hydrologic balance is average, and that nuclear production is at a normal level. As the electricity market has become more integrated, the cost of the marginal production technology determines the price for electricity. As mentioned above, this is often coal-based production. This entails that the oil price becomes a factor when studying the price formation in the market for generation of electricity. The price of coal has a positive correlation with the price of oil. That is also the case for the price of gas. During hours of peak demand, more expensive production forms are needed to cover the demand in the market. This will lead to higher prices. In order to clarify these factors the following sub-section will examine the electricity prices in the Nordic market in the second half of 2007. This will hopefully make it easier to understand the mechanisms that determine price formation. The focus of the section will then switch to the external factors which are becoming more important due to the continuous integration of the electricity sector.

3.1 Historic Prices; 2007 and Hydro-power's Role as Price Setter

The second half of the preceding year, 2007, is an interesting sample in order to understand the dynamics of the electricity price. In Norway, the summer of 2007 was characterized by a great deal of precipitation. It was estimated to be almost 200% above what is considered to be a normal year. The hydro power producers went into this period with a surplus of 9 Twh in the hydrologic balance. The hydrologic balance refers to the storage of water in the reservoirs. This surplus at the start of the summer combined with the unusually wet summer, lead to pressure on production. This implies that the producers of hydro-power have to increase production in order to avoid water literally spilling over. The electricity produced exceeded the export capacity in the transmission grid from the Norwegian areas, and we could therefore observe record low prices at this time. The prices in the Norwegian price areas were significantly lower than the rest of the Nordic region. The system price was naturally located between the low-price area of southern Norway, and the higher price in the rest of the Nordic area.

Figure 3.1: Electricity prices



Source: Nordpool.com

The final quarter of 2007 showed an increase in the system price. This reversal of the tendency towards record low prices in the summer illustrates a distinctive characteristic of the Nordic market for generation of electricity, namely the *water value.* This term refers to the fact that water has an alternative cost in producing one unit of electricity today. When a producer of hydropower lets water flow through the turbines, they can not utilize the water again. On the other hand, saving too much water means they run the risk of letting valuable water spill out of the reservoirs. Hence, the producers of hydro-power face a rather complex optimizing problem.

In the fall of 2007, the Norwegian producers approached this problem by withholding production in anticipation of higher prices in the first quarter of 2008. The beginning of 2008 marked the beginning of the second period of ETS. This second stage of the quota-system was expected to lead to higher values for the quotas, and a corresponding higher price of electricity. Producing electricity is also considered to be more beneficial in the winter due to winter climate, with colder weather and snow instead of rain. As a result of hydro power producers' reduction in production, one could observe that the *system price* converged towards early 2008-prices at the end of the year. The figure above shows that both the system price and the area price for southern Norway declines during the first weeks of 2008. This tendency has also continued after week nine. Data from Nord Pool reveals that the reduction in the price for NO1 is larger than the system price after week nine. This observation indicates that the production of hydro-power can offer an explanation. The following figure can possibly shed some light on this matter:

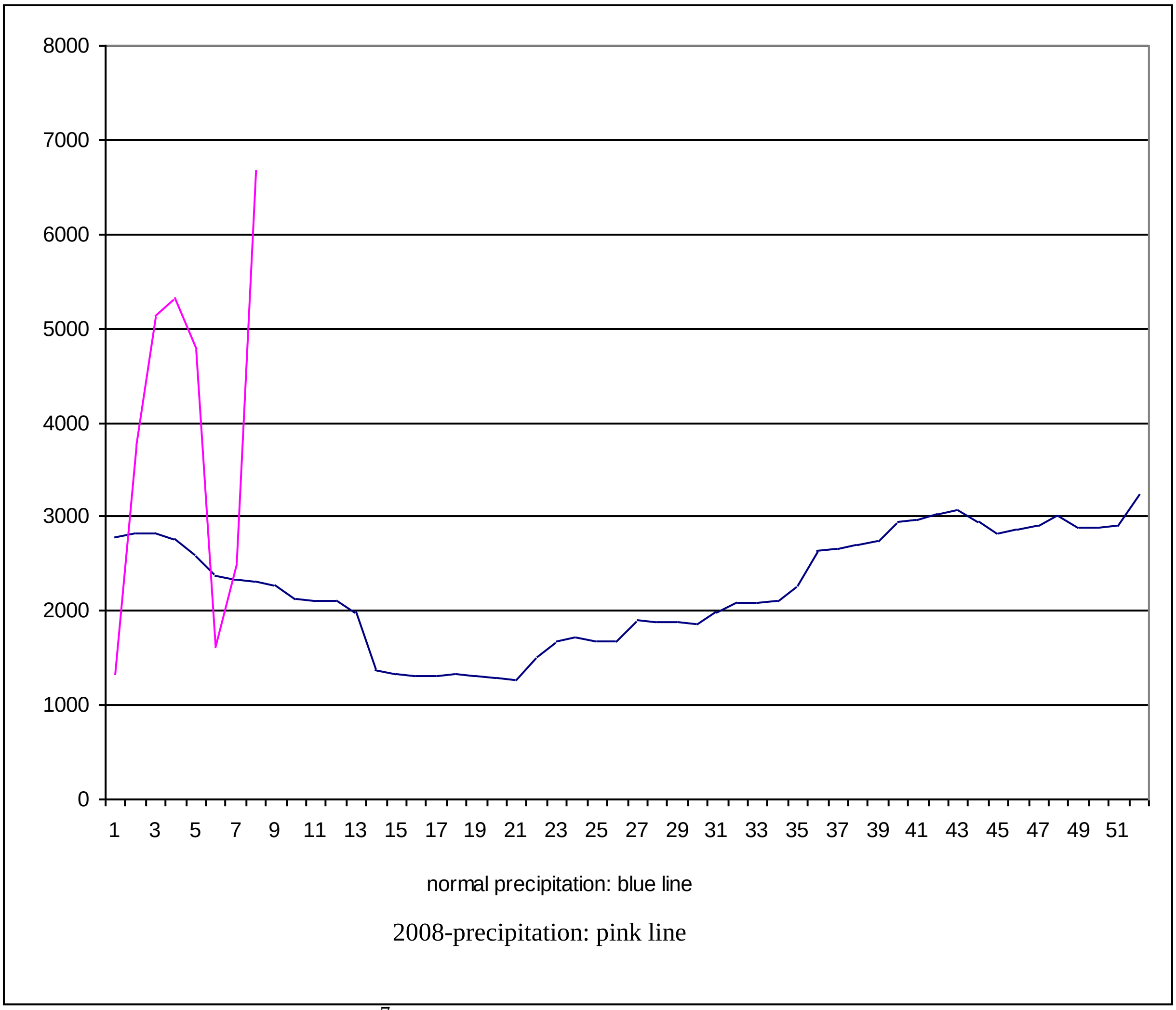


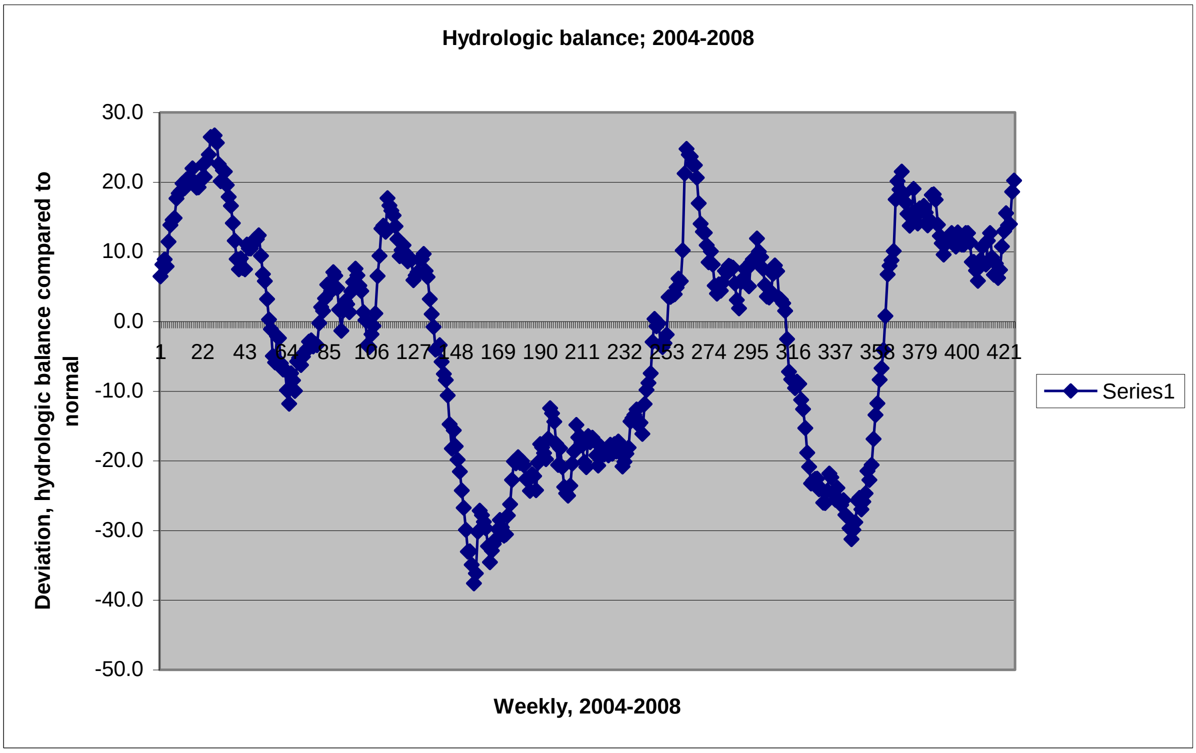
Figure 3.2, Source: Fjordkraft[7]

Figure 3.2 shows unusually high levels of precipitation during the first part of 2008. The hydrological balance, which will be explained below, is positive when entering this period. These two factors combined lead to a situation comparable to the summer of 2007. Producers of hydro power face pressure on production, and an increase in production reduces prices. I have not found data concerning the transmission capacity for this period of time. Nevertheless, an educated guess is that the price for southern Norway follows the system price until the export capacity from NO1 is reached.

[7] Meeting with John Brottemsmo, senior analyst Fjordkraft

The two latter paragraphs show that hydro-power is important in regard to price formation in the Nordic electricity market. It is widely acknowledged that the direct marginal cost of production for hydro power is close to zero, but the *water value* is added to this marginal cost as an alternative cost. The physical characteristics of water as production input is also a factor which contributes to making hydro-power a price setter. The capacity limits of the transmission grid is also worth noting, as hydro-power only contributes to a fraction of the electricity production in the Nordic region as a whole. Without a congested transmission grid, the variation in hydro-power production would not affect the electricity price as much. The production of hydro-power has the greatest impact on price formation under "abnormal" circumstances, or in other words, when the hydrologic balance is upset. A significant surplus in the reservoirs and snow reserves leads to pressure on production and corresponding low prices. If there is a deficit, one is dependent on import of electricity from surrounding areas. In this case one will observe higher prices due to lack of production of hydropower. *Fjordkraft* has quantified the interval of hydrologic balance to be within 10 TWh deficit or surplus.

Figure 3.3: Hydrological balance



Source: Fjordkraft

This plot of the hydrologic balance from 2004 until today clearly shows that the state of hydrologic balance, using *Fjordkraft's* estimate, is not to be taken for granted. It seems that during this time period, the market is frequently in a state of imbalance. In light of the discussion above, this would underline hydro-power's role as a price setter in the market.

When the market is in the state of hydrologic balance, other variables have a greater impact on the price formation in the Nordic market for generation of electricity. The next sub-section will examine these other factors.

3.2 Price Formation in an Integrated Nordic Electricity Market

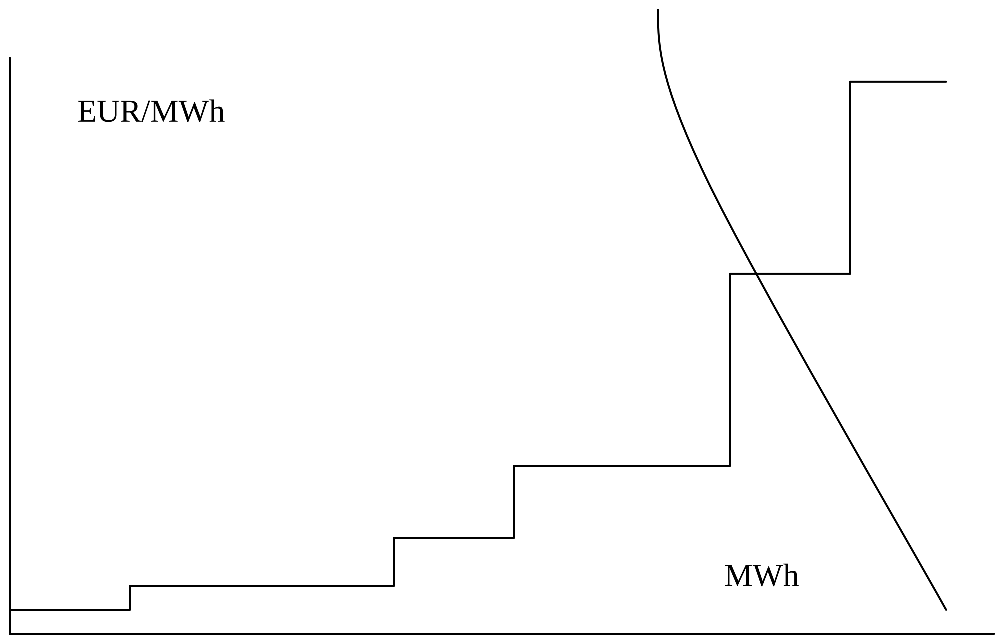
The previous sub-section showed the relevance of hydro power in regard to the price formation in the electricity sector. This result is somewhat surprising, since production of hydro power is characterized by low marginal costs. In section two the competitive environment of the industry was debated. The conclusion was that the environment resembled that of an oligopoly. However, the traditional way of viewing the competition and the price formation in the Nordic electricity market is Bertrand competition with asymmetric marginal costs. For the time being, it is useful to use the assumption of price competition with asymmetrical marginal costs in our analysis:

The equilibrium in the case of price competition with asymmetrical marginal costs of production follows directly from the discussion of the *Bertrand paradox*, which is thoroughly presented in the introductory section. Assuming two firms competing, the firm with lowest marginal costs will charge a price marginally below its competitor's price. The firm with the competitive advantage will obtain a profit equal to the difference between the marginal costs:

$$c_1 < c_2$$
$$p = c_2$$
$$\pi_1 = (c_2 - c_1)D(c_2)$$
$$\pi_2 = 0$$

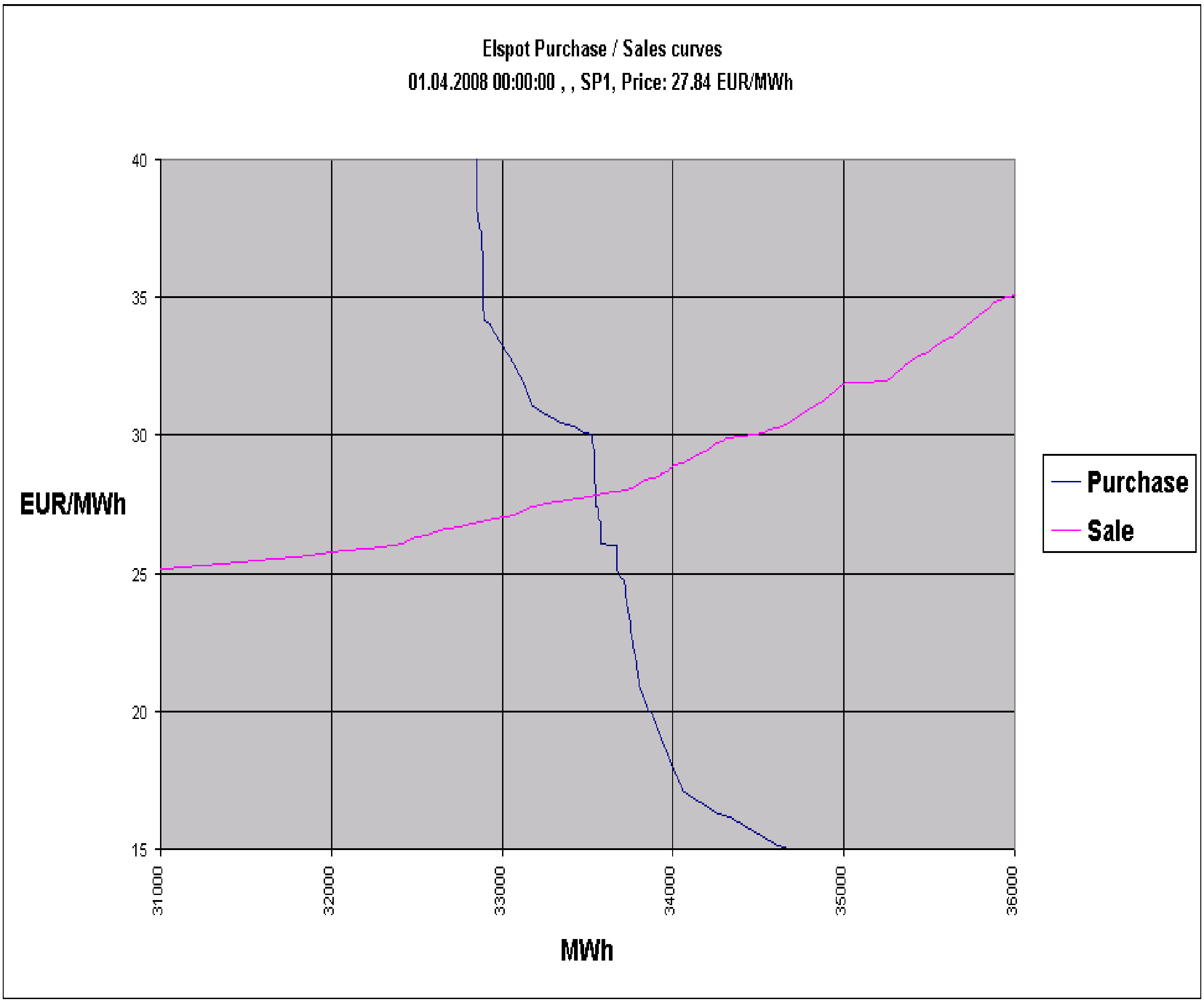
This model is useful for explaining the observed characteristics of the electricity market. The supply and demand curve has distinctive features, and is a useful tool in order to predict and explain the development of the electricity price in the Nordic region. This approach to the problem is widely accepted among market participants when analyzing the market. The supply and demand curve will be presented below. In this regard it is important to remember that the role of hydro power as price setter during certain hours slightly distorts the picture.

Figure 3.4: Market cross, theoretical



The figure shows the distinctive features of the supply and demand curve. The production of electricity includes several different production technologies. Each of these has different marginal costs of production. This leads to the “ladder-shaped” supply curve which shifts upwards at the threshold for each production technology. This mechanism continues with a corresponding higher price until the demand has been satisfied. The outer part of the supply curve is steep and in hours of peak demand one can observe large jumps in the electricity price. During these hours peak power generators are used, which generally involves very high production costs.

Figure 3.5 Market cross, empirical



Source: Nordpool.com 2.4.2008

Figure 3.5 shows the market cross for the Nordic electricity market as it is observed on Nord Pool on the second of April 2008. Nord Pool defines the system price based on the aggregated supply and demand in the market. Market participants report to the exchange both volumes and at which price they are interested in buying or selling. Nord Pool then matches these and the market obtains the system price. These data are published with a one day delay. (This is why the system operators (TSO`s) sometimes have to perform countertrade in order to make sure the volumes of trade from Nord Pool are fulfilled.)

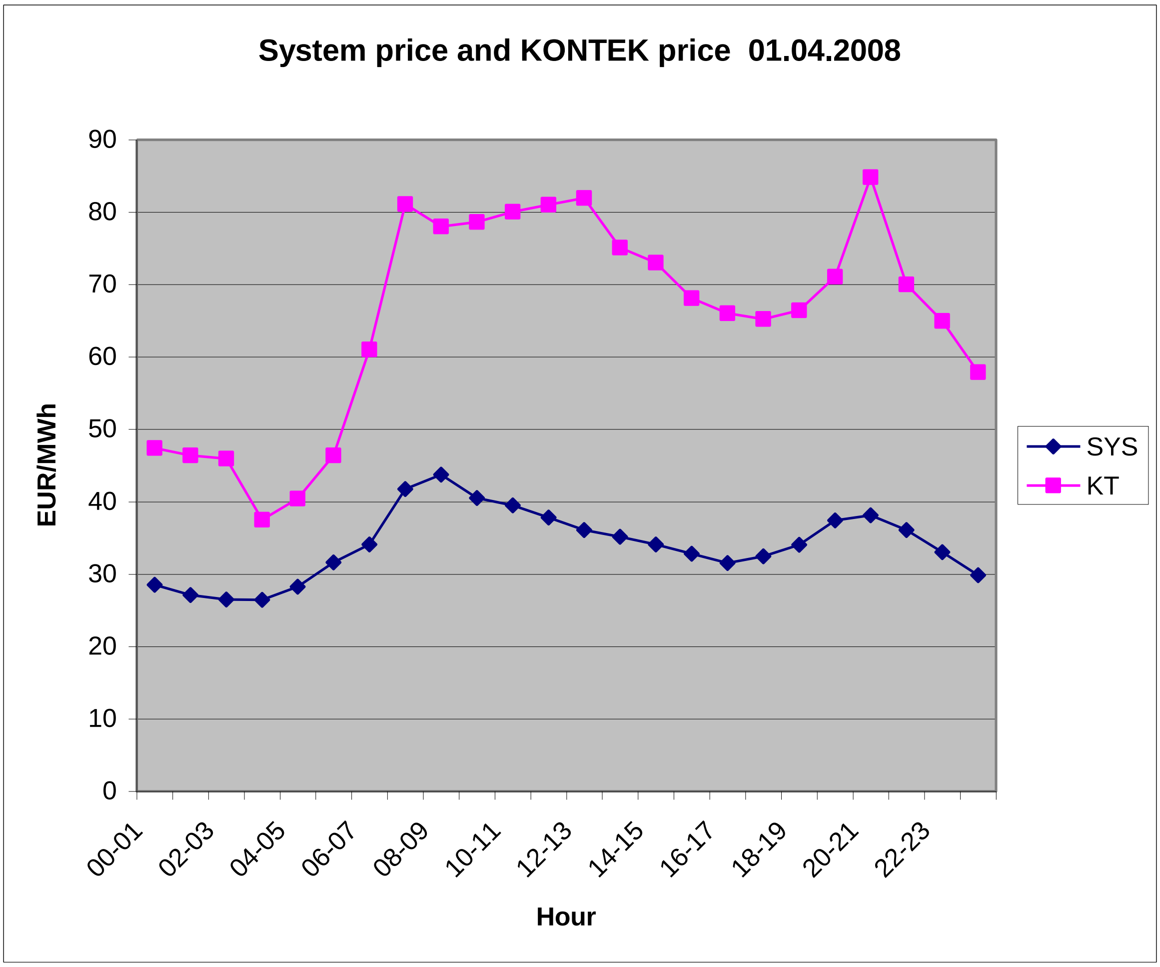
The empirical supply and demand curve which is presented in the figure does not at first sight correspond with the theoretical curve presented above. There are several reasons that cause this deviation. Firstly, the empirical figure shows a snapshot of a small interval around the market cross of the aggregated supply and demand curve. This will distort the impression of the supply curve, and neither the ladder shaped structure nor the steepness for higher volumes will be observable. Secondly, the market cross on the second of April this year showed a system price of roughly 28 EUR/MWh. This price is relatively low and places us well to the left in the theoretical supply and demand diagram. In other words, at this price level the more expensive production technologies placed at the outer rim of the diagram are not relevant. Thus, the steepness of this part of the supply curve does not clearly materialize in the figure from Nord pool.

The supply curve is, as we can see, somewhat complex and has several interesting features. The demand curve is perhaps more straight-forward. The demand side was thoroughly examined in the previous section. The empirical figure from Nord Pool confirms the results from this discussion. The demand for electricity was earlier described as relatively inelastic because of lack of substitutes and lack of transparency in the market. Consumers do not have any alternative sources of energy at present, and they cannot monitor the price from hour to hour. The inelasticity of demand gives us the steep demand curve, which can be observed in the figure above.

The steep demand curve underlines the importance of the various different production technologies for the price formation in the Nordic market for electricity.

The more expensive production technologies are often characterized by a low level of flexibility. The flexibility of production is a key to understanding the mechanisms that affect the price today, and will be even more important in the future. The German market for electricity differs significantly from the Nordic market, partly because of lack of flexibility. The demand in the German market is to a great extent supplied by electricity produced from coal. Power generators based on coal cannot be switched off in response to change in demand. It is too costly to stop and restart these generators. As a result, the German prices are high during day-time, and correspondingly low during nights. The following figure illustrates this.

Figure 3.6: German and Nordic electricity prices



Source: Nordpool.com

Figure 3.6 shows the Nordic system price and the price from the German El-spot area (KONTEK). In line with the reasoning in the previous paragraph, the German price fluctuates more during the 24-hour orbit than the Nordic price. It is interesting to note that the German price is constantly higher than the system price. This means that the German price area is net importer from the Nordic region throughout the day. This particular result obtained on the first of April 2008, is dangerous to generalize. A recurrent scenario is that the Nordic region is net importer at night, while net exporter in daytime.

The figure above is an interesting comparison of the two different electricity markets. Unfortunately, it is not possible to draw any conclusions from a plot of the prices on one random day. Nevertheless, it illustrates some important aspects regarding the price formation in the Nordic market. The significant volatility of the German price during the different hours of the day underlines the value of the flexibility that the producers of hydro-power have. At present, the value of this flexibility is somewhat limited due to the capacity constraints on the transmission grid. In the future this is expected to change. With future transmission capacity which is not limited by congestion between the Nordic region and the KONTEK-area, the prices will converge. It is difficult to accurately quantify the effects this will have on the Nordic electricity price, but the accepted view is that it will lead to a higher price. The Nordic producers will naturally benefit from a higher price, and this development will be enhanced by the increased ability to optimize production in hours of higher prices.

3.2.1 Further Integration of the Nordic Market in Near Future

The last paragraph concluded with the claim of an improved future transmission capacity between the Nordic countries, as well as between the Nordic region and continental Europe. This suggestion has important implications and will be addressed here. Furthermore, on the basis of the figure of the German and Nordic electricity prices, the last sub-section revealed that the effects will result in higher electricity prices in the Nordic region. The capacity constraints are one of the main factors that limit the competition in the market. The Nordic competition authorities welcome the expansion of the transmission grid in order to enlarge the market. The authorities claim that this will enforce competition. It seems like a paradox that a scenario which will imply higher prices is optimal from a competition point of view. It is not necessarily the aim of this thesis to perform a thorough welfare analysis. Nevertheless, it is interesting to obtain an overview of the plans for developing the transmission grid in order to examine the effects on the future price of electricity.

The process of expanding the grid has accelerated during recent years. Today, the export and import capacity from the Nordic region to surrounding areas are respectively 3650 and 5530 MW[8]. Roughly 50 percent of these capacities originate from links established within the last nine years:

2000: SwePol, 600MV
2003: Finland-Russia, +450MW
2006: Estlink, 350MW
2007: DK1-Germany, +300/+150 MW
2008: NorNed, 700 MW

There has been a dramatic increase in transmission capacity in recent years. This trend is expected to continue. A further 3500 MW of capacity is anticipated to be added to the transmission grid within 2015[9]. The development indicates that the convergence of the Nordic and continental European prices is going to be a reality soon.

As noted above, this is expected to raise the Nordic prices. The rationale behind this reasoning is simple. The marginal cost of production is higher for thermal production of electricity. This production technology is dominant in central Europe. In dry years one can at present observe Nordic prices that are higher than German prices. This is mainly due to the constraints on import capacity to the Nordic region. It is important to note that this scenario is the exception that confirms the rule. The Nordic prices are generally lower, and it is therefore legitimate to conclude that convergence will lead to higher prices in the Nordic region. This future

[8] Conversation with *John Brottemsmo*, senior analyst, Fjordkraft
[9] NORDEL (the organization for Nordic TSO's), 2008, www.nordel.org

development is welcomed by the Nordic producers. The Norwegian producers of hydro power should be especially pleased. They are able to adjust production on an hourly basis in order to optimize the value of production. This is valuable today, but will be even more profitable when the producers will have unrestricted access to the continental market in the near future. Increased profit will be obtained by exploiting the differences in prices during a daily 24-hour orbit. (See figure of German daily prices above)

This particular result is of great interest for the purpose of this thesis. The fact that the Nordic price is expected to coincide with European prices will make it easier to establish the effect of the quotas on Nordic prices. The added cost of CO_2 will have a direct effect on the electricity produced from thermal power which is dominant in continental Europe. And with converging prices, this direct effect will also apply to the Nordic prices. The next section will make use of this result in order to examine the price effects of the quotas. The rest of this section will discuss other variables which influence the price formation in the market.

3.3 Other Price Factors

The preceding parts of this thesis discussed hydropower's role as price setter, as well as the importance of coal-based production in periods of hydrological imbalance. Furthermore, the importance of the continuing integration of the Nordic market for generation of electricity was underlined. This sub-section will focus on other variables that also have a significant impact on the price formation in the market. We have earlier mentioned that a financial market with electricity as the traded commodity is fully developed. In recent, years hedge funds as well as other investors have discovered the possibility to take positions in electricity products in order to diversify their portfolios. Raw material is often negatively correlated with the financial markets. These markets are thus valuable when investors are trying to reduce risk. The effects of the financial market concerning electricity are becoming increasingly important, but will not be further elaborated in this thesis. The focus will be on oil prices, in addition to coal and gas prices. The goal of this part of the work is to examine the mechanisms that shape the price of these commodities, now and in the future. This will be important when the next section discusses the price effects of CO_2-quotas.

3.3.1 Oil Price

The price of oil is a parameter which is considered important in many aspects of the economic world. Many countries rely on oil, and an increase in the oil price often has dramatic effects. It is somewhat difficult to obtain full insight regarding this market, and one encounters even more problems when trying to forecast future development of the oil price.

Supply of oil comes from countries which are blessed with oil reserves. Examples are Norway, Canada and the Arabic nations. There is a great level of demand uncertainty since a large part of the oil supply origin from politically unstable areas. A few of the suppliers are also engaged in, or on the brink of, war activities. These factors push the spot-price of oil upwards since it is an advantage to hold oil, instead of buying forward. The demand for oil is to some extent dependent on the general activity of the world economy. In recent years the demand for oil has increased, especially from the emerging economies in Asia. The last factor mentioned here is the US dollar. The price of oil is named in US $. The last year has been turbulent for the American currency. The dollar was traded for roughly 6.20 NOK in early 2007, and on the 12 of April 2008 it was traded below 5.00 NOK for the first time in about 20 years. The depreciating dollar reduces the oil price in real terms.

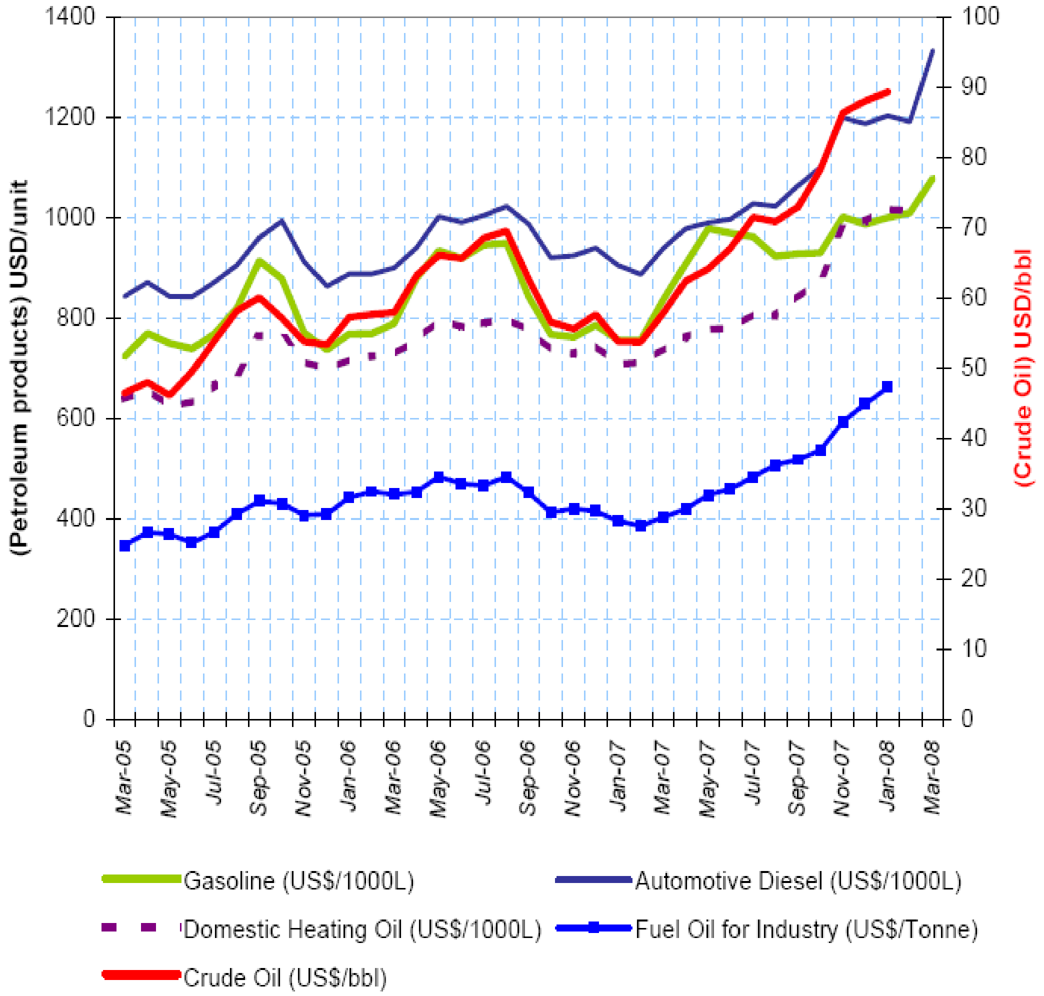


Figure 3.7: Oil Prices Source: International Energy Agency, March 2008[10]

The recent period has brought record-high oil prices. The magic boundary of 100 US$/barrel was broken in early 2008. The growth in the global economy is expected to slow down in the near future. The financial markets are currently in deep turmoil. This is a factor which indicates a lower oil price. Nevertheless, the demand for oil is relatively inelastic and the unstable Middle-East region is not likely to improve in the near future. However, it is beyond the limits of this thesis to provide a meaningful forecast of the future oil price.

[10] http://mailing.iea.org/

3.3.2 Coal Price

The price of oil does not affect the electricity price directly. However, the oil price influences other variables, which in turn have a great impact on the price of electricity in the Nordic countries. The price of coal offers an example. As mentioned above, the marginal cost of production of coal is decisive for the electricity price in the Nordic region. The marginal cost can roughly be divided into the price of the raw material, the coal, and the price of a CO_2-quota. This underlines the importance of a discussion concerning the price of coal. The latter part of 2007 showed an increase of the coal price of roughly 50 percent, from 80 US$/ton to 120 US$/ton. The increase in price for coal delivered to Europe is caused by both increased transportation costs and a rise in price of coal sold from exporters. Coal used in European electricity production originates mainly from South Africa. The transportation costs increased first during the fall of 2007. Coal is transported by means of dry-bulk. This implies that coal is transported on big ships, and competes with respect to price with other raw material such as iron, in addition to grain. The rise in transportation costs came because of reduced port capacity in South Africa. Furthermore, the economic growth in China led to an increased import of iron. A final factor influencing the transportation costs for coal during the fall of 2007 was that Australia was forced to import grain because of a failed harvest.

After the increase in freight charges, the price of coal delivered Europe was pushed further upwards due to the fact that the price of the raw material itself increased:

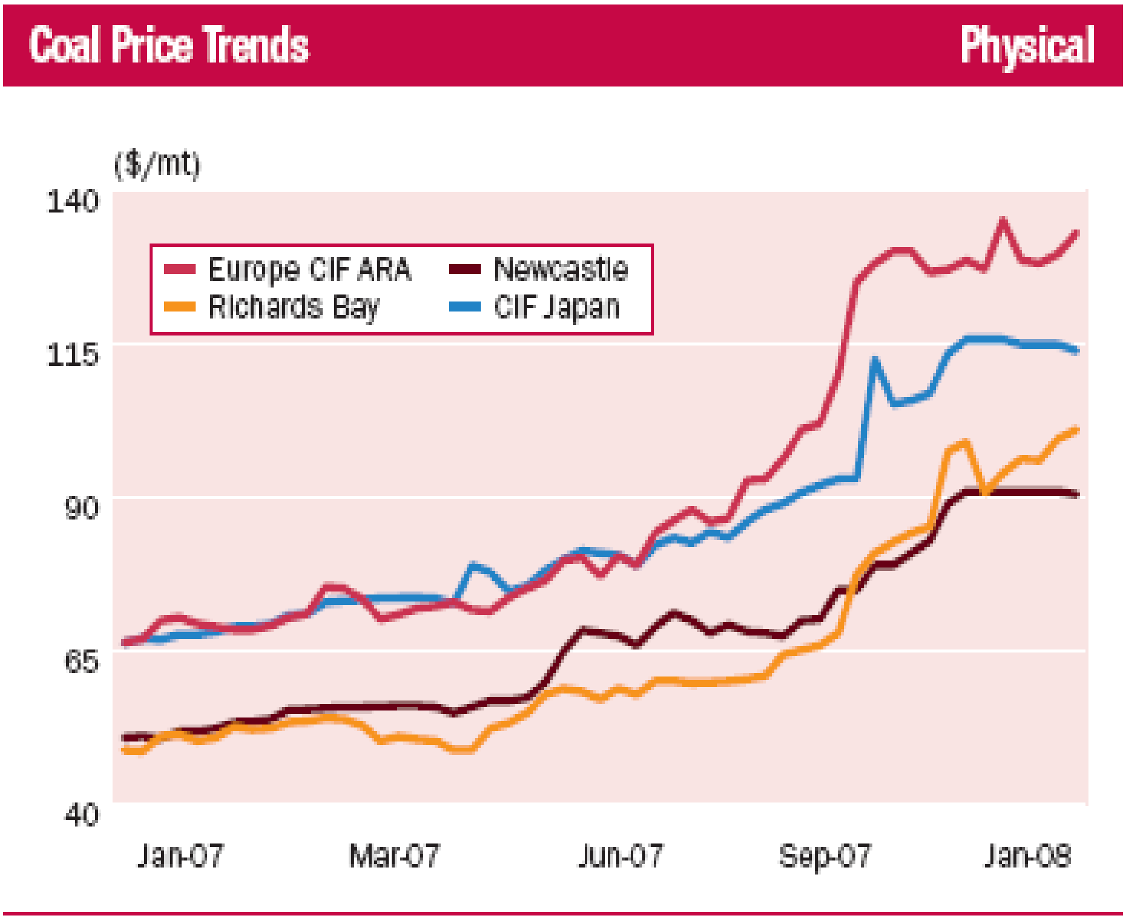


Figure 3.8: Coal Prices, Source: Coal Trader International, Jan 18. 2008[11]

The price of coal delivered from exporting nations is determined by the conditions of supply and demand. These mechanisms are rather complex and difficult to predict. The freight charges are somewhat easier to grasp. The financial market, by the means of forward prices, is expecting a lower price of coal delivered Europe the next three years (see figure below). Capacity of dry-bulk will increase, since 500 new ships are expected to be built within the next few years. The port capacity in South Africa will also be improved. These factors indicate a lower price of coal delivered Europe, but the freight charges are closely tied to the oil price:

11 http://www.platts.com/Coal/Newsletters%20&%20Reports/Coal%20Trader%20International/See%20A%20Sample/index.pdf?o=v

FOB Richards Bay

Jan 08	100.35	100.65	100.50	0.50
Feb 08	99.35	99.65	99.50	0.25
Q1 2008	99.50	99.80	99.65	0.40
Q2 2008	97.10	97.40	97.25	-1.25
Q3 2008	96.10	96.40	96.25	-0.25
Q4 2008	96.10	96.40	96.25	0.25
2008	97.20	97.50	97.35	-0.20
2009	91.35	91.65	91.50	-1.25

Figure 3.9: Forward prices, coal   Source: Coal Trader International, Jan 18. 2008

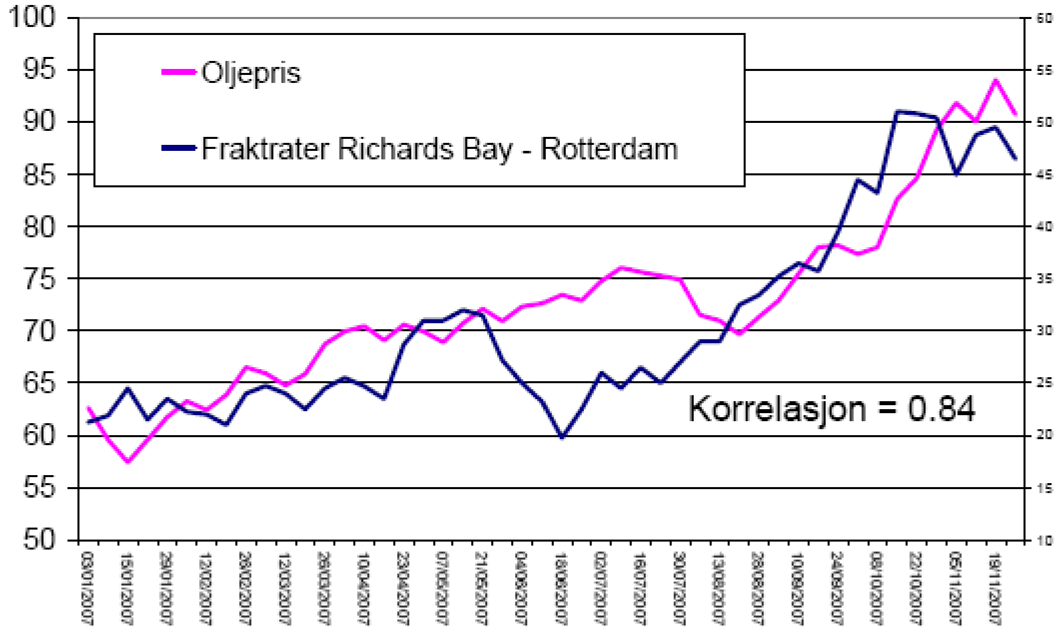


Figure 3.10: Correlation of oil and freight charges   Source: John Brottemsmo, Fjordkraft

The financial markets expect a lower price in the next few years. This is possible to explain by the means of reasonable arguments concerning the expected development in dry-bulk in the near future. Nevertheless, the figure indicates that the uncertain oil price to some extent dictates the future price of dry-bulk transportation. The first part of 2008 has brought record-high coal prices. The background for this is the simultaneous effects of supply trouble and a large demand for coal.

3.3.3 Natural Gas Prices

The price of natural gas is an interesting aspect of the future development of the energy market. Generation of electricity from natural gas is not competitive compared to coal production. The marginal cost of production of electricity from natural gas is roughly 75 EUR/MWh. Hence, the production of electricity with this technology is rarely profitable with the prices we at present are observing in the market. This could change in the future when the quota-regime is fully developed. Furthermore, the structure of the market for natural gas is evolving. As previously mentioned, it is a goal for this thesis to explore whether natural gas can obtain competitiveness compared to coal-based production. There seems to be a need for a radical change in order for this to happen. The marginal cost of production of coal is about 35 EUR/MWh, which is about half of the marginal production costs for natural gas.

The market for natural gas is structured mainly in the form of long-term contracts. The British market is an exception, where the market resembles the Nordic spot market for electricity. The prices of the long-term contracts are generally far above the prices in the British spot market. The reason for this is that the contracts are tied to the oil price. This seems counter-intuitive. One would expect that producers of natural gas, which often also produce oil, would like to hedge oil price-risk by means of selling natural gas. This reasoning would also apply to oil-importing nations. One would assume that buying natural gas could be an alternative in periods of soaring oil prices. Natural gas could then represent a gain in the form of diversification for both oil- exporting and importing countries. The rationale behind tying the contracts to the oil price is to guarantee the profitability of extracting the natural gas resources. Trading of natural gas implies investments in infrastructure in the form of pipelines. (Natural gas is also transported in liquid form in ships.) Producers will therefore demand a guarantee of profitability in the form of contracts tied to the oil price, before they decide to extract the natural gas resources from oil fields. The market for natural gas has also been relatively unstable due to delivery uncertainty. Russia has a significant part of the world's natural gas resources. Importers of natural gas have been reluctant to make themselves completely dependent on Russian gas, as the Russian political environment has been perceived as unstable. Several countries have in fact accurately quantified the maximum proportion of import coming from Russia. The consequence of this is that countries will purchase natural gas from more expensive sources in order to get a more reliable supply.

The long-term contracts tied to the oil price are the main reason why the price of natural gas has followed the upward trend of other natural resources. This can change in the future. When the long term contracts expire, we develop a spot-based market, like the one which is already developed in Great Britain. There is also a great deal of delivery uncertainty today since many countries are semi-dependent on natural gas from Russia.

4.0 The Introduction of CO_2-quotas

The development of the European trading scheme (ETS) is the EU's response to the Koyoto agreement. The *Koyoto-agreement* has its background in the *United Nations Framework Convention on Climate Change* (UNFCCC), which was signed by 154 countries in 1992 with the goal of stabilizing the emissions of climate gases. In 1997, the UNFCCC was elaborated with the signing of the *Koyoto-protocol*, when several industrialized countries committed themselves to reduce emissions below 1990-level. The EU has to reduce the emission of climate gases by 7% compared to the 1990 emission. Russia signed the agreement in 2004, and thereby the conditions for the protocol to become effective were fulfilled.

As mentioned above, the introduction of the ETS came as a direct consequence of the requirements imposed on the European Union by the *Koyoto-protocol*. Economists have long been convinced that market intervention in the form of quotas is the right way to approach an environmental problem like the one we are faced with now. An individual actor does not have the incentive to cut its emissions. Hence, market intervention is necessary in order to achieve reduction of emissions. Problems arise when trying to determine the effective way to intervene. Individual restrictions without opportunities to trade will not achieve cost effective reduction. The rationale behind a quota-based system is that market forces will lead to a cost effective reduction of the emissions of climate gases. In other words, market participants with superior cleaning technology will sell quotas in the market at a price above the marginal cleaning cost. Conversely, an actor with high cleaning costs will choose to purchase quotas in the market at a price below its marginal cleaning cost. This process will continue until an equilibrium is reached where the market price of the quotas is equal to the marginal cleaning cost of all market participants.

This rationale behind the quota-system will be presented more formally later in this section. As noted, economists generally agree on this subject. Nevertheless, many non-economists need convincing before they accept that a market-based tool is the right way to approach this environmental problem. The ETS is a pioneer project that is being closely monitored by academics and public officials around the world. The experiences with the ETS will be very important regarding the future of such a market-based weapon against climate changes. USA was one of the strongest supporters of a quota-system in the early stages, since it has had positive past experiences with market based reduction of sulfur. By contrast, the European Union was at first skeptical towards the idea of a quota system in order to reduce emissions. The conditions changed drastically however, when the US refused to accept the terms of the *Koyoto-protocol.* USA's withdrawal from the negotiations was a massive blow. The world's richest country is also the largest contributor to emissions of greenhouse-gases. The parties are painfully aware that an effective reduction in emissions requires a global commitment. This is where the ETS will play an important role. If the trading of allowances turns out to be a success, the rest of the world will probably be more inclined to enter into similar projects. The European Union has an advantage in coordinating a multi-national agreement like the ETS. The European Commision (EC) represents a strong central authority with the means to impose sanctions on countries that do not comply. One of the main challenges when implementing a multi-national regime like the ETS, is that the individual countries have no incentives to obey the rules set by a coalition of countries.

The next sub-sections will present the experiences to this date concerning the quota-system, as well as the future outlooks. In addition, the formal model of the quota-system will be presented. In the introduction of this thesis it was claimed that the quotas can be interpreted as an imposed tax. We will therefore, in light of the results in the preceding sections, also elaborate on the *imposed tax-model.*

4.1 The ETS; 2005-2007

The first period of the trading scheme started in 2005 and was finished by the end of 2007. These three years were designed as a trial period in order for market participants to get familiar with the market, in addition to the establishing of market infrastructure. One of the challenges in the first period of the system was the uncertainty regarding the future prospects for market participants. The member countries were all aware that the allowances for this period solely had the purpose of establishing the framework for an arena of emissions trading. The allowances were allocated to market participants based on historic emissions levels. The reductions imposed were relatively mild, and experts predicted early that the price of the quotas would be close to zero. The reason for this assumption was simply that the restrictions imposed on the 25 original EU member countries were too conservative. Naturally, the value of the quotas will to a great extent depend on the scarcity of allowances. The allocation of allowances, known as the National Allocation Plans (NAP) will decide the scarcity. First we will look at the development of the price of the quotas during the first period of the ETS. The end of the period proved the experts right, in that price of quotas was zero. Nevertheless, the price during the trial period was often high. This was especially the case at the start of the three-year period:

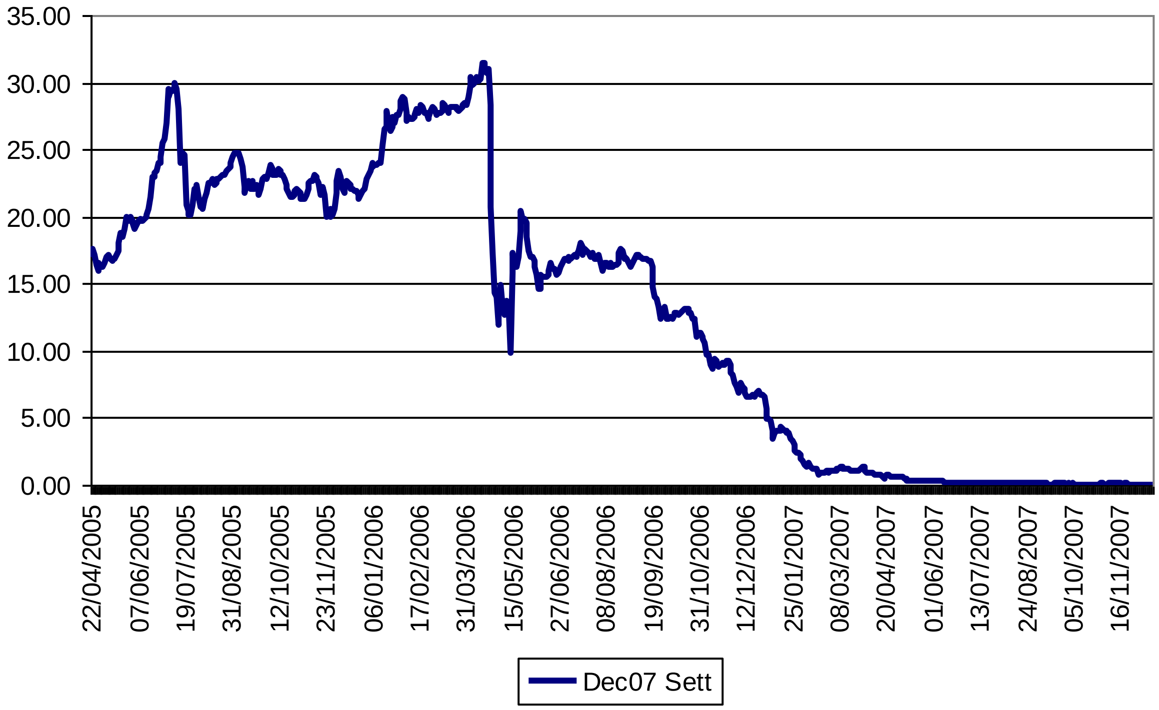


Figure 4.1: Quota prices Source: European Climate Exchange (ECX)

The figure above shows a market distinguished by a high level of volatility. The contracts in question are future contracts with settlement in December 2007. As mentioned above, the first half of the trial period was characterized by surprisingly high prices. There are several factors which influence the value of the allowances. It is quite intuitive that the potential and costs for reducing emission affects the quota-prices, but the new market also responds to fossil fuel prices as well as temperature and precipitation. The volatility also underlines the importance of a stable political foundation.

The price of the quotas will co-vary with the price of oil and natural gas. The reason for this is that higher prices for liquid fossil fuels will lead to a shift in the raw material for electricity production, from oil and natural gas to coal. The emission level of coal-based electricity production is twice that of natural gas. This will naturally drive up the demand for CO_2-quotas, and hence lead to a higher price. The above paragraph also argued that the value of allowances is dependent on temperature and precipitation. This mainly has its background in the structure of the Nordic electricity market, which under normal conditions is partly supplied by hydro-power. In dry years the production of hydro power is reduced. The demand for fossil fuels increases in order to cover the demand for electricity, and thereby also the demand for allowances. The last factor influencing the price of the quotas is the political regulatory framework. The market for trading in quotas is new. In order to establish a functioning market, the information available to market participants must be as complete as possible. The volatility in the first period of the ETS can partly be explained by the quality, or lack of, available information. Market participants faced many uncertain variables. Firstly, the allocation of allowances was only for the first period. Everyone was aware that the allocation would be reduced in the period after the trial period, and that scarcity would be increased in the future. This factor gave incentive to purchase allowances for later use. To some extent, this helps explain the high price of allowances in the early stages of the three-year period. Secondly, the level of verified emissions was difficult to predict. The figure above shows a sharp decline in the price in May 2006. This dramatic price reduction came as a result of the release of verified emission data for 2005. The announcement was unexpected, and several member countries simultaneously reported lower emissions than experts had forecasted.

This sharp and unexpected decline brought voices of concern regarding the high level of volatility. It seems that the market for trading in allowances strongly needs reliable sources of information before a stable investment environment can be finalized. The latter part of the trial period showed declining prices that approached zero. This was, as noted above, more in line with the predictions of analysts. The volatility seemed to decline towards the end of the three-year introduction phase, and this is possibly a positive indication for the future of the ETS. The second part of the agreement began at the start of 2008. The next sub-section will study the development in the early stages of the *Koyoto-period*, which will end in 2012.

4.1.2 ETS; The Koyoto-period 2008-2012

The second part of the ETS is called the Koyoto-period. The name reflects that the goal of this phase is for member countries to achieve the reduction of emissions, as outlined in the *Koyoto-protocol.* In order for this to be a success, the allocation of allowances has to be more restrictive than was the case in the first period. In other words, the scarcity of the quotas should increase. If this was the case, one would expect to observe an increased price of the allowances. We are now only a few months into the second phase of the ETS, and it is naturally too early to draw any conclusions regarding the success of the *Koyoto-period*. Nevertheless, there are already interesting data available that give an indication of the development:

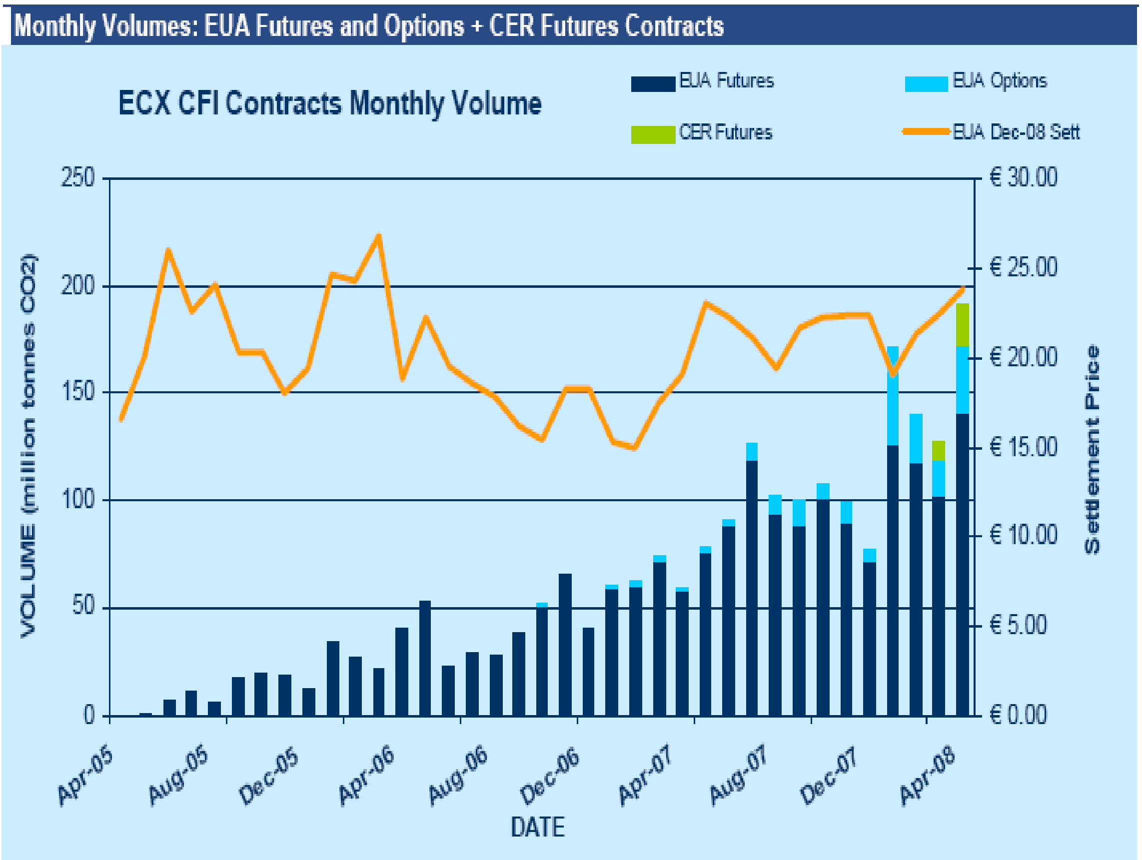


Figure 4.2: Forward contracts, price and volume   Source: ECX

The contracts in question here are future contracts with settlement in December 2008. The data reflect trading in these contracts from the start of the ETS, up until April 2008. April of this year gives the latest data available. The discussion of the trial period reveals a volatile market. The figure above indicates a reduction in the volatility for the second phase of the trading scheme. Even if it too early to draw conclusions, the tendency of reduced price fluctuations offer positive signs for future prospects of the arrangement. The volatility of the

December-08 contracts was already relatively stable with respect to price during the trial period. Furthermore, the figure indicates that the price of the contracts has reached an even higher level of stability in the first quarter of 2008. The price for an allowance of one metric ton of CO_2 settled in December 2008 is expected to be around 20-25 Euro. This stable tendency would indicate that investors are satisfied with the transparency of the market, as well as the general stability of the conditions in the investment environment. If this is the case, we will probably observe an increase in traded volume. The data from the above figure confirm this. The total volume traded in these contracts has increased steadily from the start of the period, which is natural for a market in the starting phase. More importantly, the volume growth accelerated at the end of the trial period. This tendency continued into the early stages of the *Koyoto-period*. The increased volume is a strong signal from the market participants that the ETS has succeeded in establishing an apparently well functioning market for trading in quotas. The strictly positive and stable price of the allowances indicates that the allocation of the allowances has reached its objective, namely to create a scarcity that in turn assigns a significant value to the quotas. In order to further examine the proposal that the quotas are priced within the interval of 20-25 euro pr metric ton, it is interesting to study the price of futures with different settlement dates. If the stable characteristics from the December-08 contracts can be generalized to the longer contracts, it would substantiate the assumption of a well-functioning market. The following figure presents the various different contract types in the same diagram:

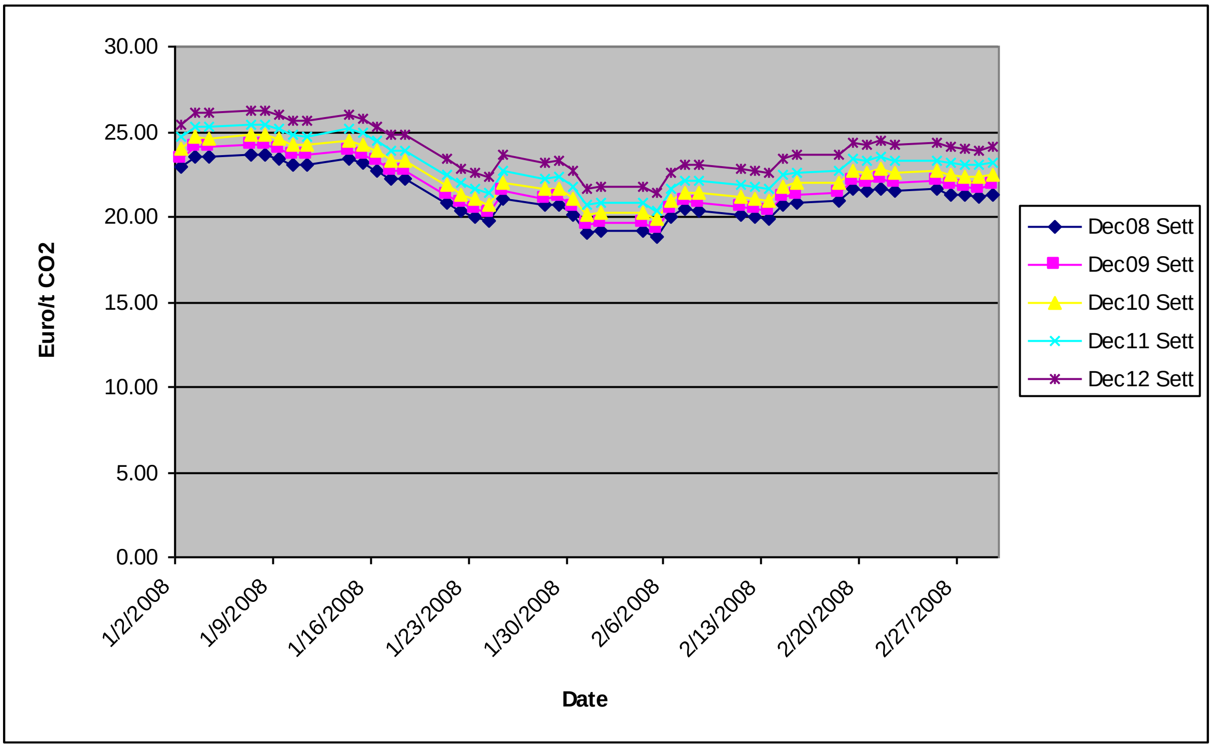


Figure 4.3: Forward contracts Source: ECX

The diagram indicates somewhat surprising results. The allowances are valued at the same price regardless of the settlement date. The reason for this is that the Koyoto-commitments are based on average emission levels for the four-year period from 2008-2012. In addition, investors have chosen to purchase the contracts with the nearest settlement date (December 2008). Nearly the whole total volume of trading has been in 2008-contracts. We have to question the reliability of these data and be careful not to define the price from the figure above as an absolute truth, only a few months into the second phase of the ETS.

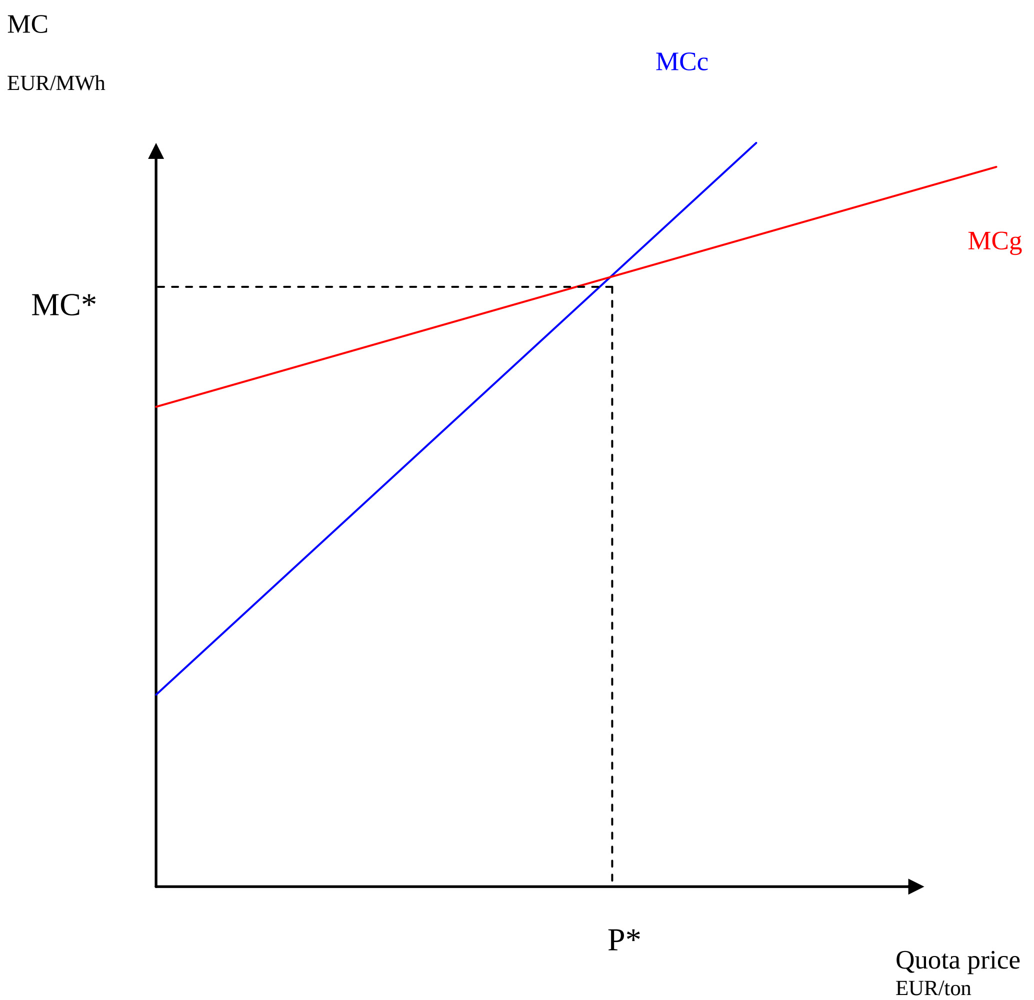
4.2 Coal versus Natural Gas-based Production of Electricity

The above discussion gives hold to interesting results for the purpose of this thesis. The object of the work is to predict how the introduction of quotas will influence the price and production in the Nordic electricity market. It is therefore quite useful to discover these structural aspects of the newly emerged market of quotas. The volatility is reduced and there seems to be a consensus of the value of the allowances. This will make it possible to discuss the implications for the price of electricity. As mentioned earlier in this thesis, the value of the quotas will be added to the marginal cost of production for coal-based production of electricity. Economic theory suggests that a quota based system will lead to cost effective reduction in emissions of greenhouse gases. Market participants with low marginal cleaning costs will sell quotas and actors with higher costs will purchase quotas. This process will continue until the marginal cost of cleaning is equal to the market price of the quotas for all players. The theory concerning quotas does not include the factor of different production technologies. In order to include this distinctive feature of the electricity market in the discussion, an example will be presented in the next paragraph.

In the electricity market, one can view the marginal cleaning cost as a switching cost.
In order to illustrate this, we can assume a producer of electricity with a coal based production. This producer now faces an externally imposed production cost equal to the value of a CO_2-quota. This is to be considered a cost even if the allowances are allocated to the producer free of charge. The reason for this is that the opportunity cost of the quota is to sell it in the market. For the purpose of this example we will assume that the producer has access to the technology needed to produce electricity from natural gas, in addition to coal. Furthermore, there are no costs involved when changing between the two different production technologies. The last assumption is that the marginal cost of production consists only of the price of raw material and the value of an allowance, in other words, the efficiency of the two fossil fuels is assumed to be equal.

The producer will then optimize its production under the new market conditions. The carbon intensity of electricity production from coal is roughly twice that of natural gas based production. The producer will reduce the part of the marginal cost of production originating from emission by around 50% of the value of the quotas by choosing natural gas as its production input. When following the reasoning in this simplified example, the ratio of the difference in price of raw material to the quota price will decide which production technology the producer will choose. The idea of considering the marginal cleaning cost as a switching cost originates from the fact that a coal based producer will purchase quotas as long as this is more profitable than switching to natural gas. This assumption does not take into consideration the rigidity of the electricity production. Nevertheless, the reasoning might be valuable when considering long-term development. If one can obtain a significant switch in production from coal to natural gas, the level of emission would be reduced. The figure below illustrates the mechanisms:

Figure 4.4: Marginal cost of production for coal and natural gas-based production



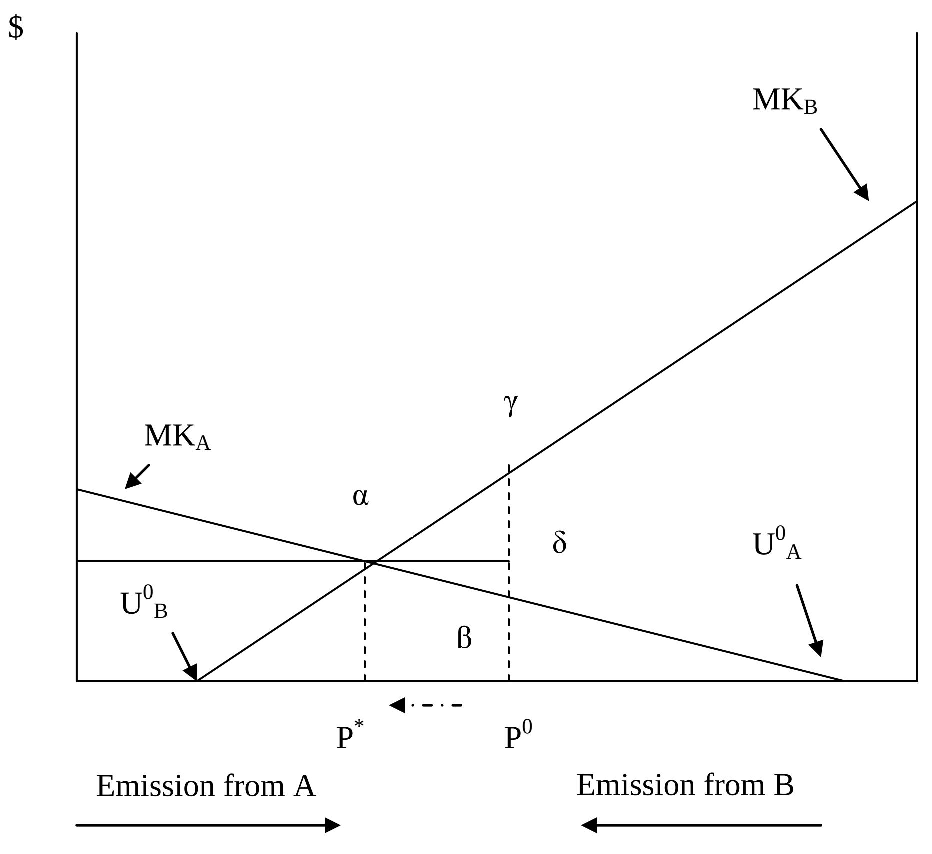
The figure represents the marginal cost of production of electricity from coal and gas. The red line is for coal, while the blue line is for production based on natural gas. In the example from the above paragraph it was assumed that the marginal production cost solely consists of the price of raw material in addition to the marginal cost involved with the emissions of climate gases (the market price of quotas). These two dimensions can be identified in the figure. The intersection of the cost curves with the y-axis shows the marginal cost of production when the quota price is zero. Thereby, the price of the raw material is given by the intersection of the curves with the y-axis. Natural gas is, at present, roughly twice as expensive as coal. The slope of the curves is given by the carbon intensity of the two production technologies. As claimed above, the carbon intensity is greater for coal. Hence, the slope of the marginal cost as a function of the quota price is steeper for coal than for natural gas. P* represents the threshold level for the quota price where the hypothetical producer will be indifferent to using coal or natural gas as production input. When the value of the quotas is above P* natural gas will be the preferred production input, while coal will be more competitive with a lower quota price.

The notion of production switching from coal to natural gas is intriguing and its success will, as noted above, depend largely on the price of the various different fossil fuels. The previous section discussed the past and future development of the oil, coal and natural gas prices. At present, the record high prices of raw material indicate that a switch to natural gas is not happening in the near future. The marginal cost of production for coal-based electricity generation is estimated to be around 35 Euro/MWh, while it is roughly 75 Euro/MWh for natural gas. The value of the quotas is at present between 20-25 Euro/ton. One of the conclusions from the preceding section is that it is difficult or impossible to predict the future price of the fossil fuels. Nevertheless, there are indications that the structural aspects of the natural gas market are about to change. The infrastructure is constantly improving, and one might see the end of the long term contracts which have dominated this market in the past. This kind of evolvement is a necessity in order for natural gas to obtain competitiveness compared to coal. The situation today is that the price of both these natural resources is closely linked to the oil price. They therefore have a great deal of co-variation. It is difficult to imagine that co-variation will be reduced in the immediate future. Nevertheless, the soaring prices of raw material in recent years have illustrated the high volatility of these markets. The quota-prices after the *Koyoto-period* will also affect the competitiveness of natural gas.

4.3 A Formal Model of Quotas

Economists world-wide have embraced the idea of a quota-based approach to the reduction of emissions of climate gases. As mentioned above, the assumption is that market mechanisms will lead to a cost-effective reduction, and thereby maximize the potential for reduction. This thesis is written based on the view that the introduction of quotas is a constructive way to approach the climate challenge. In order to illustrate this view, a formal model of the quotas is presented below:

Figure 4.5: Formal model of quotas



Source: Kåre P. Hagen, Økonomisk politikk og samfunnsøkonomisk lønnsomhet, figur 7, side 247.

The figure above illustrates why the notion of quotas has become so popular among economists. The main challenge the authorities face when trying to implement quotas, is that it is difficult or impossible to detect the cleaning costs for market participants. In addition, market players do not have an incentive to reveal the magnitude of these costs. Therefore, a random distribution of allowances would not lead to the optimal solution. If the allocation of quotas was at P^0 in the figure, in other words evenly distributed between A and B, one would obtain a deadweight loss equal to the triangle made by α, β, γ. The reason for the ineffectiveness of the allocation is the difference in marginal cleaning cost. From the above figure we see that A has a significantly lower marginal cleaning cost than B. This problem is easily solved by making the allowances open for trade in the market. Because of the asymmetric marginal cost of cleaning, B will purchase quotas from A. This will continue until the equilibrium in P^* is reached. A will choose to sell these allowances since it can obtain a price in the market which is higher than its marginal cost of cleaning. The equilibrium shows that A will, at a lower cost, reduce its emissions significantly more than B. The price of the quotas is given by the horizontal line which ends at δ. This price is equal to the marginal cost of cleaning for all market participants. It is worth noting that this model assumes that there are no market players with the ability to influence the market price. In addition, the emissions levels have to be observable. The central authority behind the system has to be able to monitor the compliance of the market participants for the threat of sanctions to be feasible.

The model discussed above shows the fundamental economic principles behind a quota based system in an elegant way. It can be applied to fishing quotas, as well as emission of climate gases. The electricity market is complex with respect to the fact that it includes several different ways of generating electricity. These production technologies all differ in emission levels. Therefore, it was argued earlier in this section that the marginal cleaning cost can be viewed as a switching cost between different means of production. This complicates the model above to some extent. The question is whether the complexity of the electricity market will make a quota-based system less effective. The answer to this is probably no. The legislators, in this case the European Commission, who impose the allowances on the market, are not concerned with how the emissions are reduced. It is irrelevant whether the producers of electricity switch from coal to gas, or if they choose to invest in cleaning technology to reduce emission from existing production. The model implies that given a sufficient shortage of quotas, one will obtain a reduction of emission. Furthermore, the reduction level can be accurately pinpointed by the amount of allowances allocated. These factors are still valid given the characteristics of the electricity market. The conclusion from this discussion is therefore that the quota-system has every opportunity to be successful. The results from the sub-sections regarding the experiences to this date from the ETS support this. The market infrastructure is developed and the liquidity of the market has improved significantly in the transition from the trial period to the *Koyoto-period.* The reduced volatility is also a positive factor worth noting in this regard.

4.4 Tax Incidence under Imperfect Competition

The conclusion from the section concerning the competitive environment was that the market resembles an oligopoly with quantity competition. This description is assumed to be a satisfactory one at present, and this sub-section will present a theoretical model of the price effects of an imposed tax in this scenario.[12] The model assumes symmetrical players in the market. This is not correct in the electricity market, due to the asymmetrical marginal costs of production. Nevertheless, this model shows in an elegant way, how imperfect competition can lead to surprising price effects from an imposed tax:

$q_i =$ Output firm $\qquad \sum_i Q_i = Q$ = total output

τ_v = ad valorem tax on output $\qquad \tau_s$ = unit tax on output

In the case of the quotas being imposed on the producers in the electricity market, the ad valorem tax can be set to zero. An ad valorem tax is value-based tax, in other words, it is dependent on the price being charged by the producers. The quotas are analogous to a unit tax. The tax is only dependent on the amount of output, in other words, the quotas are a function of only q_i. This implies that emissions are proportional to output. In other words, the amount of emission from the electricity production is constant per unit of output. This condition is vital when arguing that the quotas are analogous to a unit tax.

When assuming identical firms in a symmetrical equilibrium, and that the number of firms is fixed, we obtain:

$$\pi(q_i) = (1-\tau_v)\,p(Nq) - c(q_i) - \tau_s q_i \qquad \textbf{(4.4.1)}$$

[12] Fullerton, D. and G. Metcalf, (2002), "*Tax incidence, Working Paper",* 8829, NBER, Cambridge

First order condition:

$$(1-\tau_v)p'(Nq)\times q+(1-\tau_v)p(Nq)-c'-\tau_s=0 \quad \textbf{(4.4.2)}$$

Differentiating **(4.4.2)** with respect to τ_s yields:

$$((1-\tau_v)p''(Nq)Nq+(1-\tau_v)p')\frac{dq}{d\tau_s}+(1-\tau_v)p'N\frac{dq}{d\tau_s}-c''(q)\frac{dq}{d\tau_s}-1=0$$

(4.4.3)

Isolating yields:

$$\frac{dq}{d\tau_s}=\frac{1}{(1-\tau_v)p'(\frac{p''Q}{p'}+1+N-\frac{c''}{(1-\tau_v)p'})} \quad \textbf{(4.4.4)}$$

This expression can be simplified by defining:

The producer price: $p^*=(1-\tau_v)p$

The elasticity of the slope of the inverse demand curve: $\mu=\frac{p''Q}{p'}$

The measure of the relative slope of the demand and cost curves: $k=1-\frac{c''}{p^{*}{}'}$

Substituting these expressions into equation **(4.4.4)** yields:

$$\frac{dQ}{d\tau_s} = \frac{N}{p^{*}{}'(\mu + N + k)} \qquad \textbf{(4.4.5)}$$

These results enable us to study the price effects of an imposed tax:

$$\frac{dp^*}{d\tau_s} = (1-\tau_v)p'\frac{dQ}{d\tau_s} = \frac{(1-\tau_v)p'N}{(1-\tau_v)p'(\mu+N+k)} = \frac{N}{\mu+N+k} \qquad \textbf{(4.4.6)}$$

The expression from equation **(4.4.6)** enables us to study the theoretical price effects of an imposed unit tax. When setting N=1 we have the monopoly case. In this scenario over-shifting (the price effect exceeds the size of the tax imposed) occurs when $-1 < \mu + k < 0$ Linear costs implies that *k=0* since *c''=0.* Therefore, over-shifting occurs when $-1 < \mu < 0$. Linear demand and costs can never lead to over-shifting. The derivative of the producer price with respect to the unit tax is then 0.5.

The rationale for the over-shifting is that producers anticipate the reduction of demand due to the increased price. The firms will be interested in compensating the decrease in demand by charging a higher price. The elasticity of the slope of the demand curve will decide if the firms will increase the price more than the size of the tax. The key here is that the demand and cost curves can have different slopes for different parts of the curves. The relationship of the slopes of the cost and demand curves will be the crucial variable.

The assumption of linear costs is plausible for electricity production. We can assume that there are insignificant economics of scale in this market. Holding on to the assumption of linear costs implies that the value of *k* is zero. In this scenario, equation **(4.4.6)** reveals that the tax incidence is solely dependent on the competitive structure on the supply side (represented by N) and the elasticity of demand (μ). This is interesting and in line with other parts of this thesis. The competitive structure of the market and the elasticity of demand have been devoted much attention earlier. The above paragraph discussed potential over-shifting in the monopoly case, when the value of N is one. When the value of N increases, μ becomes less important. Over-shifting is maximized in the monopoly case. When N approaches infinity, the value of **(4.4.6)** converges towards one. A value of N which approaches infinity is the free competition scenario, and when the derivative of price with respect to the unit tax is one the consumers are forced to absorb the whole tax. This result is intuitively reasonable since a prefect competition scenario would imply price equal to marginal cost. The imposed tax could then be interpreted as an addition to the marginal cost of production. As the marginal cost curve is horizontal, the price would then be equal to the original marginal cost of production in plus the imposed tax. The variable μ is more difficult to describe. We have seen that the elasticity of demand is inelastic, at least in the short run. Discussing the slope of the demand curve at different points of the curve is beyond the scope of this thesis.

The above model describes the economic factors that influence the price effects of the introduction of quotas. The next section is meant to elaborate and summarize the findings in order to examine the price effects in the electricity market. This model is a good benchmark in that regard.

4.5 Future Price Effects of the Quota Regime

This last sub-section regarding the quotas will tie up the loose ends. The relevant results from the competition analysis will be related to the findings in this section. The purpose of this thesis has been to examine the price effects of the quotas. For the time being, we are almost five months into the second phase of the quota regime. The timing has enabled us to obtain data for the market price of the quotas. As we have seen, the value of the allowances is currently roughly 25 Euro/ton. There is no reason to believe that this value is ever going to decrease. It is more likely that the officials will tighten the allocation of the quotas in the years after the *Koyoto-period*, which ends in 2012. Therefore, it is a reliable conclusion to claim that the quotas have obtained a significantly positive market value, and that this value will at least amount to 25 Euro/ton.

The challenge we are facing is to determine how this value will affect the electricity price in the Nordic market. A few models have been presented earlier, which more or less enlighten us in this matter. The first step in order to determine the price effects is to decide which model is most fitting for our problem. This brings us back to the competition analysis. The conclusions from the analysis of the competitive environment were that the market was highly concentrated, and that market players compete with quantity as the decision variable.
The congested transmission grid is the reason for the highly concentrated market. Developing this grid further is highly recommended by the Norwegian competition authorities. This will lead to a larger market and thereby enhance competition. The improvement of the grid is already under way, and will be continued in the near future. We will then probably see a convergence of the electricity prices in continental Europe. Since the generation of electricity on the continent consists of production based on fossil fuels, this will imply higher prices in the Nordic countries. It will also mean that the quota price will have a direct price effect on the Nordic market. The Nordic producers of hydro-power, which are large by the Nordic scale, will emerge as price takers instead of price setters. Therefore, it is not reasonable to assume a highly concentrated Nordic electricity market in the future.

The second result from the competition analysis is that the market participants compete in quantities. The argument is that the capacity constraints on the competitors soften the competition, and that every producer faces a residual demand. It is always difficult to represent a complex real market by means of simple models. Our result is partly based on the concentrated Nordic market, and the concurrent oligopoly. Based on the reasoning above, we have claimed that this scenario is not likely in the future. A larger electricity market will be better described by price competition with asymmetrical marginal costs of production. As we have seen, this model is already useful in explaining the price in the Nordic market. Under normal conditions the marginal cost of coal production can be identified from the *spot- price* on NordPool. This is of course based on the assumption that the marginal cost is well known.

Consequently, the present market is best described as an oligopoly characterized by quantity competition, but in the future the price competition model is relevant. This will be the basis for the task of predicting how the quotas are going to affect the future price level. The model of tax incidence under imperfect competition (Cournot oligopoly) shows that a tax can be passed onto consumers by a multiple exceeding one. This result is interesting, while the most recent conclusion represents a scenario which is not likely to be the case regarding the quotas. Models based on price competition yields, conveniently enough, more clear-cut conclusions. In a situation with price competition the tax burden will be completely passed onto the consumers in the Bertrand equilibrium. Also, the model of tax incidence with Cournot competition revealed that when N approaches infinity (perfect competition), the change in price with respect to the imposed unit tax was converges towards one.

These results are based on the assumption of price equal to marginal cost in equilibrium. This is not too far off the mark in the electricity market with the price being determined by the cost of the marginal production technology. Furthermore, the result is based on a sufficient inelasticity of demand so that the demanded quantity does not decrease significantly. An elastic demand relative to supply could lead to a situation where a production technology with lower marginal cost of production would become more price-decisive. This would make the discussion of the price effects of the quotas more complex. Earlier we have seen that the demand for electricity has to be considered inelastic in the short to medium run. The last condition that needs to be addressed here is that the pecking order of the production technologies is not going to be altered. In other words, coal must not lose its competitive advantage compared to e.g. natural gas. The discussion from the preceding sub-section regarding the competitiveness of coal compared to natural gas revealed that this last assumption is also reasonable.

5.0 Concluding Remarks

The answer to the main problem of the thesis is thus that the burden of the quotas will be passed on to consumers. The theoretical models which are implemented indicate that the value of the quotas as whole will be represented in the end-user price. We have also reached interesting conclusions regarding other aspects of the quota regime. The empirical data retrieved from the European Climate Exchange give reasons for optimistic future outlooks for the ETS. The market infrastructure is established and the liquidity is improving as we speak.
The following paragraph will summarize the findings that lead to this result. The latter parts of the concluding remarks will discuss the reliability of the results as well as the possibilities for future research in this field.

The section regarding the competitive environment focused on the present conditions in the Nordic electricity market. The results based on this discussion revealed that the market resembles an oligopoly with quantity competition. The demand was labeled as inelastic in the short run. These findings would indicate that the relevant model would be tax incidence under imperfect competition with *Cournot-competition*. The complexity of the market distorts the picture. Another finding in the competitive analysis is that the Nordic market will be integrated with the market in continental European market in near future. This means that the present market structure will change. This problem concerning the competitive structure and how this affects the relevant models was dealt with in section four, which presented the price-effects of the quotas. Section three discussed the price formation in the electricity market. This section was important in order to understand the factors which influence the price in the Nordic electricity market. One of the important results in this section is that the marginal cost of coal-based production determines the price under normal circumstances. As a consequence, the connection between the value of the quotas and the price formation in the Nordic market is easier to grasp. The reason is that the quotas will have a direct effect on coal-based production, and the quotas will thereby also have an indirect effect on the price in the Nordic market. The section regarding the price formation argues that the model of price competition with asymmetrical marginal costs of production has a significant explanatory power. Section four tries to tie up all the loose ends, in order to establish the price effects of the introduction of quotas. The biggest challenge in this regard is deciding which model is most relevant in order to determine the price effects of the $C0_2$-quotas. The answer to this is that price competition is the optimal model because of the future integration of the markets.

The answer to the main problem is based on the assumptions which are thoroughly discussed in section four, but the most important condition is possibly the claim that the quotas can be interpreted as a unit tax. This argument is a building block in the thesis. The fact that we can model the price-effects of the quotas as a unit tax makes it possible to use well known economic theory. The problem of imposing a tax on production has been thoroughly examined before. The models which are presented in this thesis enable us to obtain the results which were presented in the last section. The main argument for treating the quotas as a unit tax is that the quantity of emissions is constant per unit of output (electricity production). This is, as previously explained a reasonable claim.

The preceding theoretical analysis leads us to the conclusion that the value of the quotas as a whole will be passed on to the consumers in the form of a higher electricity price. This claim is based on strict assumptions. Firstly, the elasticity of demand needs to completely inelastic. Secondly, we have to assume that the producers of coal do not have significant operating margins on their production. The last assumption is that the Nordic hydro producers are 100 percent price takers in the market. The last assumption is probably the most robust condition in the long run. The result of future integration of the European electricity markets, and subsequent convergence of prices, is possibly the most reliable conclusion in this thesis. In line with preceding discussions, the first two assumptions are also legitimate. Nevertheless, the most important source of uncertainty from the results is the future *value* of the quotas. The problem of predicting the exact size of the quota price which will show up in the end price of electricity will be difficult or impossible to calculate accurately. Therefore, one way of formulating the obtained result is that a significant part of the future value of the CO_2-quotas will be passed on to Nordic consumers.

The thesis has uncovered interesting results, to a large degree based on a competitive analysis and the use of models with observed explanatory power. The results are obtained by a strictly theoretical approach. The aim is to use theory to anticipate the future of the electricity market. This is naturally relatively difficult, and the obtained results are associated with a significant amount of uncertainty. As mentioned several times earlier, the ETS has only just begun. An empirical study would probably be difficult to perform at this point. The problems which are studied here would rather be perfect for empirical work in near future. The theoretical foundation formed here would be a useful basis in that regard. The quotas have already obtained a market value which has been estimated to be about 20-25 EUR/metric ton. This means that one should be able to study effects of the quotas on the electricity price relatively soon. The problem one will encounter in this regard is the complexity of the competitive environment, which at present is mainly caused by the congested transmission grid. Nevertheless, this new market gives hold to several interesting aspects worth studying for additional and future research.

References:

Fullerton, D. and G. Metcalf, (2002), "*Tax incidence, Working Paper",* 8829, NBER, Cambridge

Hagen, K. P. (2005), "*Økonomisk Politikk og Samfunnsøkonomisk Lønnsomhet"*, Oslo, Cappelen Akademisk Forlag

The Nordic competition authorities, (report number 1, 2003), "*A Powerful Competition Policy – Towards a more coherent competition policy in the Nordic market for electric power"*, Copenhagen, Oslo, Stockholm
http://www.kt.no/portal/page?_pageid=235,456839&_dad=portal&_schema=PORTAL&p_d_i=-121&p_d_c=&p_d_v=395668&p_d_i=-7127&p_d_c=&p_d_v=395668&p_d_i=-12732&p_d_c=&p_d_v=395668&p_d_i=-12733&p_d_c=&p_d_v=395668

The Nordic competition authorities, (report number 1, 2007), "*Capacity for Competition – Investing for an Efficient Nordic Electricity Market"*, Copenhagen, Oslo, Stockholm
http://www.kt.no/portal/page?_pageid=235,456839&_dad=portal&_schema=PORTAL&p_d_i=-121&p_d_c=&p_d_v=427536&p_d_i=-7127&p_d_c=&p_d_v=427536&p_d_i=-12732&p_d_c=&p_d_v=427536&p_d_i=-12733&p_d_c=&p_d_v=427536

Reilly J.M. and S. Paltsev, (2005), *"An Analysis of the European Emission Trading Scheme",* report number 127, MIT Joint Program on the Science and Policy of Global Change
http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt127.pdf

Singh B. and F. Skjeret, (2006), "*Ownership Relations and Cooperation in the Norwegian Power market"* SNF-report number 35, Bergen, Institute for Research in Economics and Business Administration.

Støyva G, (2005), *"CO_2-kvotenes innvirkning på den Nordiske kraftprisen",* Master Thesis, Bergen, Norwegian School of Economics and Business Administration

The European Commission, (2006),*"Building a Global Carbon Market",* report pursuant to Article 30 of Directive 2003/87/EC, Brussels
http://www.ieta.org/ieta/www/pages/download.php?docID=1992

EFTA Surveillance Authority, (2007), "*Energy Sector Inquiry Concluding Report"*, Event number 396509, Brussels
http://www.eftasurv.int/information/reportsdocuments/competitionreports/dbaFile10774.html?showWithHandler=search_v2/adv/

The European Commission, (2006), *"Auctioning of CO_2 Emission Allowances in the EU ETS",* report under the project "Review of the EU Emissions Trading Scheme", Brussels
http://ec.europa.eu/environment/climat/emission/pdf/etsreview/ets_co2_emission_auctioning.pdf

ECON, (2002), *"Simulering av Utviklingen I det Nordiske Kraftmarkedet",* ECON-rapport nr. 58/02, prosjekt nr. 33510, Oslo
http://www.econ.no/modules/trykksak/project_list.asp?mnusel=a185a190a221a

Brottemsmo, J., (2008) Meeting at the *Fjordkraft* office building, March 2008, Kokstad, Bergen

Websites:

www.nordel.org
www.nordpool.com
www.europeanclimateexchange.com