Futures and spot prices – an analysis of the Scandinavian electricity market

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***Abstract*--In this paper we first give a presentation of the history and organisation of the electricity market in Scandinavia, which has been gradually restructured over the last decade. A futures market has been in operation there since September 1995. We analyse the historical prices in the spot and futures markets, using general theory for pricing of commodities futures contracts. We find that the futures prices on average exceeded the actual spot price at delivery. Hence, we conclude that there is a negative risk premium in the electricity futures market. This result contradicts the findings in most other commodities markets, where the risk premium from holding a futures contract tend to be zero or positive. Physical factors like unexpected precipitation can contribute to explain parts of the observations. However, we also identify the difference in flexibility between the supply and demand sides of the electricity market, leaving the demand side with higher incentive to hedge their positions in the futures market, as a possible explanation for the negative risk premium. The limited data available might not be sufficient to draw fully conclusive results. However, the analysis described in the paper can be repeated with higher significance in a few years from now.**

***Index Terms*--Futures prices, price dynamics, restructured electricity markets, risk premium, spot prices.**

I. INTRODUCTION

One of the consequences of the ongoing deregulation of the power sector around the world, is that futures and forward markets for electricity have gained increased interest for suppliers and consumers of electricity. Long-term contracts provide participants in the power market with an important tool for reducing their risk exposure, and economic risk management has become more important in the new market setting. The futures and forward markets can also serve as a profitability indicator for investments in the power system, and thereby contribute to a balanced development of demand and supply. In order to use these markets in an optimal way, it is important for the power industry to gain knowledge about the information hidden in the long-term prices, and in particular the relationship between the long- and short-term prices of electricity. Scandinavia[1] is one of the regions of the world that has the longest experience with a restructured power market, and futures contracts have been traded on the Nordic Power Exchange, Nord Pool, since 1995. In this paper we take a closer look at the experiences from the Scandinavian market. In order to do this we first describe the conditions in, and organization of, the Nord Pool market. Then we look into finance theory for pricing of commodities futures contracts. The historical data from Scandinavia is analysed in order to assess the applicability of the traditional theory to the conditions in the electricity market. We are particularly interested in the relation between the long- and short-term prices in the market.

II. THE SCANDINAVIAN ELECTRICITY MARKET

A. *The history of deregulation in Scandinavia*

Norway was the first country in Scandinavia to introduce competition in the power sector when a new energy act went into effect January 1st, 1991. The act mandated separation of transmission from generation activities, at least in accounting. Point-of-connection tariffs, which help to increase the competition in the market considerably, were established in 1992. At the same time all networks were opened for third party access. A similar tariff structure was established in Sweden in January 1995, and a legislation providing for competition became effective January 1st, 1996. Finland's new energy market legislation instituted market competition beginning June 1st, 1995, and a point-of-connection tariff was introduced in November of the same year. Denmark instituted a stepwise opening of the market, beginning in 1996, but with a shorter transition period than required by the EU directives. By January 2003 the market will be fully open to competition, as in the other three countries [1].

The power exchange, Nord Pool, has evolved in parallel with the deregulation process in the Scandinavian countries.

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[1] By Scandinavia we here mean the four countries Norway, Sweden, Denmark and Finland, although strictly speaking it does not include Finland.

When established in 1993, it only served the Norwegian market. The Swedish and Norwegian markets merged into a common market, served by Nord Pool, in January ‘96. Finland joined in September ‘98, followed by western Denmark in January ‘99, and eastern Denmark in October 2000. Nordpool is owned by the Norwegian and Swedish transmission system operators (Statnett and Svenska Kraftnett), but all Scandinavian TSOs cooperate closely on operational and market aspects in the common power market. The core responsibilities of the power exchange can be summarized as [1]:

1. Provide a price reference to the power market
2. Operate a physical spot market and a financial market for derivative products (e.g. futures contracts)
3. Act as a neutral and reliable power-contract counterpart to market participants
4. Use the spot market’s price mechanism to alleviate grid congestion. Report all traded power delivery and take-off schedules to the respective TSOs

B. Supply and demand of electricity

The power generation in the three countries are based on various energy sources, as shown in Fig. 1. In Norway, nearly all electricity is generated from hydropower. Sweden uses a combination of hydropower, nuclear power, and conventional thermal power. Hydropower stations are located mainly in northern areas, whereas thermal power prevails in the south. Denmark relies mainly on conventional thermal power, but wind power’s share of the generation is rapidly increasing. The high share of controllable hydropower in the system makes it easy to regulate the generation on short notice. Hence, the spot price of electricity varies less over the day than what we see in pure thermal systems. However, the seasonal price fluctuations tend to be higher, due to the variations in inflow to the reservoirs. The price volatility is therefore high in the Scandinavian power market.

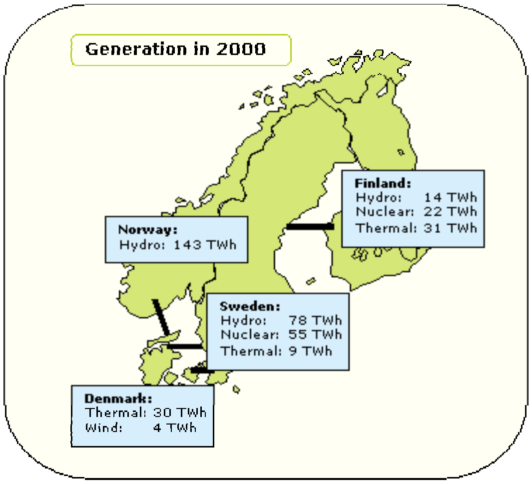

Fig. 1. Power generation by source in Scandinavia, 2000. Note that the hydro generation was record high in 2000. The generation in years with average inflow are 118, 64 and 13 TWh in Norway, Sweden and Finland respectively. The black lines in the figure represent undersea transmission lines. Source: [1].

In addition to the inflow to hydro reservoirs, the demand for electric power also plays an important role in the electricity price formation. When looking at the demand of electricity we see that the seasonal variations in electricity consumption in Norway and Sweden follow the same pattern (Fig. 2). This is because both countries use a substantial amount of electricity for heating purposes. In Denmark, where most of the heating demand is met by gas and district heating networks, the variation in electricity consumption over the year is much lower. Finland lies somewhere in between when it comes to seasonal variations. The seasonality in consumption also contributes to seasonal prices in the electricity market. Another fact that is worth noting is that there still seems to be a considerable load growth in the system. The gross consumption increased on average with 1.55 % pa. in the 90’s. Finland and Norway have experienced the highest growth rates, while the increase in Sweden and Denmark has been more modest [4].

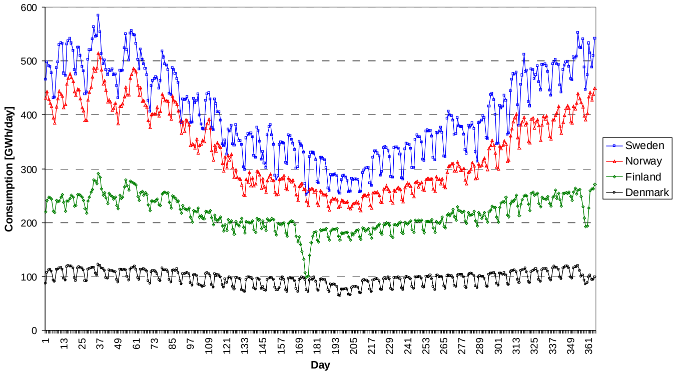

Fig. 2. Daily electricity consumption in Scandinavia, 2001. The annual figures are 147.3, 123.3, 79.1 and 35.5 TWh/year for Sweden, Norway, Finland and Denmark respectively. Source: [5].

C. The spot market

The spot market serves several purposes in the Nord Pool market area. First of all it distributes relevant neutral market information in terms of a transparent reference price for both the wholesale and retail markets. It also provides easy access to a physical market, and it creates the possibility of balancing portfolios close to time of operation. At the same time, the spot market in Scandinavia serves as a grid congestion management tool. Market splitting is used to relieve bottlenecks within Norway, and at the interconnections between the four countries. So called bidding areas may become separate price areas if the contractual flow of power between these bid areas exceeds the capacity allocated for spot contracts by the TSOs[2].

The spot market is in reality a day-ahead market, and it is based on bids for purchase and sale of hourly contracts and block contracts[3] that cover the 24 hours of the next day. The

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[2] Within Sweden, Finland and Denmark, grid congestion is managed by counter-trade purchases based on bids from generators.

[3] A block contract bid has the same fixed price and volume for a number of hours of the day.

participants use specific bidding forms to submit their bids, and the spot prices are determined through auction trade with uniform price for each delivery hour. Table 1 shows when the different activities in the spot market take place. The *system price* is calculated by aggregating the supply and demand functions from all participants in the market for each individual hour, without taking transmission congestion into account (Fig. 3). Therefore, this price is also referred to as the unconstrained market price. It serves as reference for the contracts traded in the financial derivatives market. The system price prevails throughout the whole market area when there is no grid congestion between the bidding areas. However, several different area prices might occur in periods with bottlenecks in the system. 97 TWh was traded on Nord Pool's spot market in 2000, and that amounts to about 26% of total annual generation in the market area. Fig. 4 shows the system price in the spot market since 1993.

TABLE 1
TIME LINE OF ACTIVITIES IN NORD POOL'S SPOT MARKET

Time	*Activity*
11:00	Deadline for TSOs to submit their capacity allocations for the spot market
12:00	Deadline for submitting bids to the spot market for the following day
14:00	Calculation of system price and area prices finished and published
24:00	The contract period starts

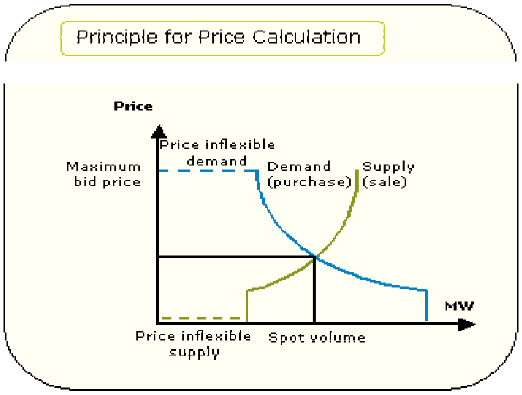

Fig. 3. The principle for calculation of the system price. Source: [2].

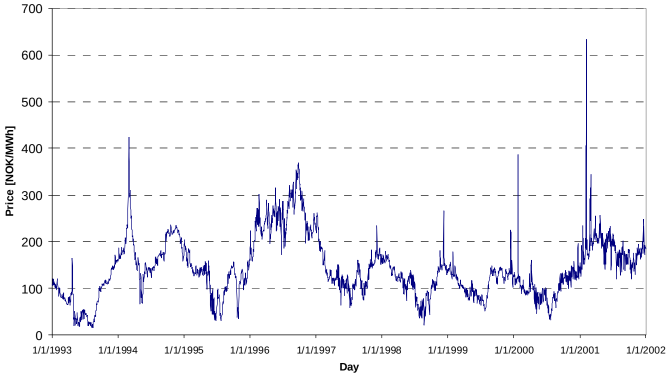

Fig. 4. System price in Nord Pool's spot market, 1993-2001. $1 ≈ NOK 9. Source: [5].

Due to the long time span (up to 36 hours) between spot market price fixing and delivery, participants may need access to markets closer to real-time. In addition to the spot market Nord Pool therefore also operates a balancing market, called Elbas. In this market participants can trade one-hour contracts until two hours before delivery. The Elbas market is currently only available for the Swedish and Finish market areas, but there are plans to extend it to also include Norway and Denmark. Deviations from the scheduled power generation and consumption in the spot and Elbas market are traded in real-time markets operated by the TSOs. These markets are used to balance power generation to load in real-time, and is open to participants who can regulate their generation or load on short notice. The TSOs in the four countries apply slightly different rules for how the real-time prices are calculated and how power imbalances are cleared.

D. The financial derivatives market

Four types of contracts are traded in Nord Pool's financial derivatives market: base load futures, base load forwards, options and contracts for difference. All four contract types are pure financial contracts, i.e. there is no physical delivery. The contracts are settled using the system price in the spot market as a reference. Hence, the physical trade takes place in the spot market. The derivatives market has been designed to serve as risk management tools for generators and retailers that want to hedge their future profit. At the same time, the market also tries to attract speculators who seek to profit from the highly volatile electricity prices in order to increase the liquidity in the market. The current organization of the futures and forward markets are further described below[4].

The *futures market* contains day, week and block (consisting of 4 weeks) contracts. The selection of available contracts is updated dynamically for every week. Trading of the daily contracts starts every Friday for contracts with delivery the following week. The block contracts are split into week contracts four weeks before the delivery period starts, while new block contracts are issued one year before delivery. Consequently, the futures market has a time horizon of 8-12 months. The settlement of the futures contracts involves a daily mark-to-market settlement during the trading period, and a final settlement in the delivery period. The mark-to-market settlement covers gains and losses from the daily changes in the market price of the futures contracts. The final price-securing settlement covers the difference between the last closing price of the futures contract and the system price during the delivery period [3]. Fig. 5 gives an illustrative example of how the settlement procedure in the futures market works. By taking a position in the futures market, and making a corresponding trade in the spot market during the delivery week, a participant is completely hedged for the

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[4] Minor modifications to the organization of the market have taken place several times since the start in Sept.-1995.

contractual volume. The settlement procedure therefore removes the basis risk from the electricity futures market[5]. Still, the participants cannot use the futures market to hedge against uncertainties concerning future load (volume risk).

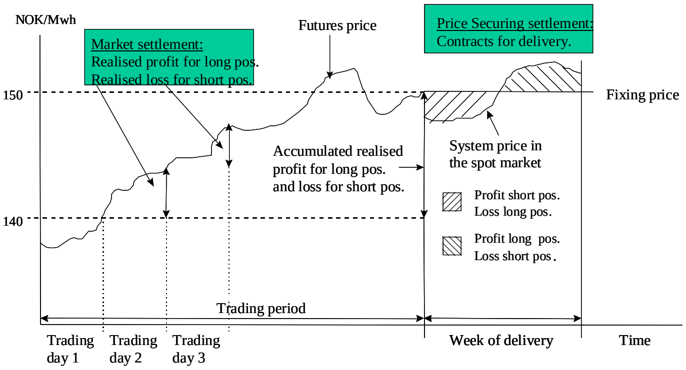

Fig. 5. Illustration of the settlement procedure for a futures contract traded at Nord Pool. The purchaser of the contract receives 10 NOK/MWh in the mark-to-market settlement. Deviations from the futures price on the last day of trading (the fixing price) is taken care of in the price-securing settlement, so that contract holder ends up with a final price equal to the initial price of the futures contract, when buying the contractual amount in the spot market. Source: [6].

The *forward market* facilitates hedging of positions further ahead into the future, and consists of season and year contracts. The year contracts are split into three season contracts[6] following specific rules, while the season contracts are not subject to further splitting. As opposed to the futures market, there is no mark-to-market settlement in the forward market. Therefore, the accumulated profit and loss during the trading period is not realized until the delivery period starts. This contributes to increase the liquidity for the long-term forward contracts, since no cash payment is required during the trading period. The additional settlement throughout the delivery period is, however, organized in the same way as for the futures contracts. The total volume traded in Nord Pool's derivatives market, including options and contracts for difference (CfDs), was 359 TWh in 2000. Estimates for the total volume of financial power contracts traded in Scandinavia in 2000 are between 1500 and 2000 TWh. This amounts to almost 5 times the annual physical power delivery, a figure that is similar to what is found in other commodities' markets ([1] and [3]).

III. FUTURES PRICING THEORY

A. The relationship between spot and futures prices

There are two main views of the relationship between commodity spot and futures prices [8]. The first theory is closely linked to the cost and convenience of holding inventories, while the second theory applies a risk premium to derive a model for the relationship between short-term and long-term prices. Both theories are briefly presented below, followed by a discussion about their relevance in the electricity market.

Inventories play a crucial role in the price formation in markets for storable commodities [7] (also sometimes referred to as "cash and carry markets"). The theory of storage explains the difference between current spot prices and futures prices in terms of interest foregone in storing a commodity, warehousing costs and a convenience yield on inventory. The convenience yield can be regarded as a liquidity premium and represents the privilege of holding a unit of inventory, for instance to be able to meet unexpected demand. By assuming no possibilities for arbitrage between the spot and futures market one can easily derive the following formula [7] for the futures price ($F_{t,T}$) at time t for delivery at time $t+T$:

$$F_{t,T} = S_t e^{r_T} + \psi_T - k_T \qquad (1)$$

where S_t is the spot price of the commodity at time t, r_T is the risk-free interest rate for the period T, ψ_T is the convenience yield and k_T is the cost of physical storage over the holding period.

The second pricing theory explains the price of a futures contract in terms of the expected future spot price ($E_t(S_{t+T})$) and a corresponding risk premium, $p_T = -(r_T - i_T)$, for the commodity. i_T represent investor's appropriate discount rate for investing in the futures contract, while r_T still is the risk-free interest rate. The futures price can now be expressed as[7]:

$$F_{t,T} = E_t(S_{t+T})e^{(r_T - i_T)} = E_t(S_{t+T})e^{-p_T} \qquad (2)$$

One way of explaining the risk premium in (2) would be to look at the conditions within the specific commodity market. An overweight of risk-averse producers wanting to hedge their products in the futures market would probably result in futures prices lower than the expected future spot price ($p_T > 0$). The opposite relation ($p_T < 0$) would occur when the demand side is the most risk averse. The risk premium could also be traced back to the concepts of storage cost and convenience yield for the commodity. A second way of explaining the risk premium is to consider the futures contract as a financial asset and compare it to other assets in the stock market. Hence, if the return on the futures contract is positively correlated to the level of the stock market, holding the contract involves positive systematic risk and an expected return above the risk-free rate is required ($i_T > r_T$ or $p_T > 0$)[8]. It is worth noting that this price theory also can be

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[5] Basis risk is usually present in other commodities markets and occurs when the futures contract does not match completely the exposure in the spot market. See [6] for a discussion about basis risk and the electricity market.

[6] Winter 1, Summer and Winter 2 cover week 1-16, 17-40 and 41-52.

[7] This formula is derived by looking at the net present value of purchasing a futures contract at time t, holding it until expiry, and selling the commodity in the spot market at time T. The net present value at time t of this investment equals $-F_{t,T}e^{-rT} + E_t(S_{t+T})e^{-iT}$, assuming that all transactions take place at time T, and that the investor earns the risk-free interest rate on the payment of the futures contract. See [12] for more details.

[8] See [6] and [9] for a further explanation of systematic risk and the futures market, and how the Capital Asset Pricing Model (CAPM) can be used for pricing futures contracts.

applied in markets where the commodity is perishable (also sometimes referred to as "price discovery markets"). The no arbitrage argument underlying (1) cannot be applied when it the commodity is non-storable, as there is no possibility of obtaining a risk-free position by buying the commodity in the spot market and selling in the futures market.

The futures market is said to exhibit *backwardation* when the expected spot price exceeds the futures price ($p_T > 0$). The term *contango* is used to describe the opposite condition when the futures price exceeds the expected future spot price ($p_T < 0$), as shown in Fig. 6.

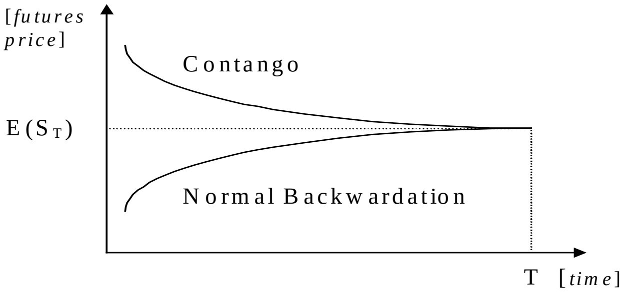

Fig. 6. Illustration of contango and normal backwardation in the futures market [9].

Before we analyse the electricity market in further detail it is worth taking a look at studies of futures markets for other commodities. *Pindyck (2001)* [7] studies the futures markets for petroleum products (crude oil, heating oil and gasoline) and finds support for the backwardation theory in these markets, particularly when the variance in the spot price is high. *Fama and French (1987)* [8] find marginal evidence of normal backwardation when 21 commodities (agriculture, wood, animal and metal products) are combined into portfolios but conclude that the evidence is not strong enough to resolve the existence of a nonzero risk premium. *Bodie and Rosansky (1980)* [10] studied risk and return in commodities futures for all major commodities traded in the United States between 1950 and 1976. They found that the mean rate of return on a portfolio consisting of their selected commodity futures contracts in the 27 years period was well in excess of the average risk free rate. Their findings lend support to the normal backwardation hypothesis. *Chang (1985)* [11] also finds evidence of normal backwardation for wheat, corn, and soybeans over the time interval from 1951 to 1980. In sum, the empirical research carried out on commodities futures prices finds evidence to support normal backwardation for some products. The risk premium may be time varying, but is not related to the general level of the stock market.

B. The electricity market

The lack of direct storage possibilities for electricity, and the physical requirement of constant match of supply and demand, makes the electricity market somewhat different from most other commodities markets. It can be argued that power generators can "store" the commodity, for instance as water reservoirs for hydropower plants or as coal for thermal power plants. However, it is not possible to buy the electricity today and store it for future sales, at least not in substantial amounts[9]. The argument about no arbitrage that (1) is based on is therefore not applicable to the conditions in the electricity market, which must be characterised as a price discovery market.

It is more interesting to look at the possible existence and motivation for a risk premium in the electricity futures market, and to what degree (2) can be used to characterise the market. A risk premium could arise if either the number of participants on the supply side differs substantially from the number on the demand side, or if the degree of risk averseness varies considerably between the two sides. Most of the companies participating in the market are both generators and load serving entities. Hence, there is no reason to believe that the futures market is biased towards any of the two sides in terms of the number of participants. However, if we look at the flexibility of adjusting the quantity on the supply and demand side there is a significant difference. The generators can control parts of their generation on a very short notice[10]. This allows them to take advantage of the price fluctuations that occur in the market, by adjusting their generation. Therefore, it does not necessarily make sense to fix the price in the futures market for all of the planned future generation. The flexibility in generation creates a possibility of profiting from the price peaks in the day-ahead spot market, and possibly also in the markets even closer to real time. The situation is different on the demand side, where the load serving entities have very limited ability to adjust the demand according to the price. Hence, it makes sense to lock in as much as possible of expected future demand in the futures market, given that the participants on the demand side are risk averse. In this sense the electricity market deviates from most other markets, where the demand side can stock up the commodity for some period ahead in time, and in that sense use the stock to adjust to fluctuating prices instead of the futures market. If the difference in flexibility on the demand and supply leads to an excess demand for futures contracts, this would translate into a negative risk premium in (2), i.e. $p_T < 0$. The futures price would, in turn, exceed the expected future spot price, and on average one would experience negative returns from holding futures contracts.

A study of Nord Pool's futures market was carried out in 1997 [6]. Hypothesis testing was used to analyse the returns

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[9] One could of course argue that consumers have the possibility to store electricity in batteries, but this option is not available in large scale. Energy systems in the future could possibly include large-scale storage capacity, e.g. in hydrogen reservoirs. On the supply side there is a limited amount of pumped hydro storage in the system today. However, all these storage options involve substantial losses and costs, and we do not see them as possible tools for making arbitrage from the difference between spot and futures prices.

[10] The fast controllable part of the power generation in the Scandinavian system is particularly big, due to the large share of hydropower in the system.

on futures contracts over various holding periods, and also on portfolios of futures contracts. The null hypothesis was that the futures price equals the expected future spot price (p_T = 0). The analysis did not find sufficient evidence to reject the hypothesis, although the results showed that the returns on the futures contracts on average were below the risk free rate (i.e. contango; $p_T < 0$). The study also looked at the relations between the returns in the futures market and in the stock market, and found no significant evidence for using the systematic risk in the futures market as an explanatory factor for the observed futures prices. The reliability of the analysis in 1997 was low, due to the short time period the market had been in operation (2 years). It is therefore of interest to revisit the problem and carry out a new analysis of the market with data that now covers more than 6 years.

IV. EMPIRICAL ANALYSIS

In the analysis of the historical data we first present some general graphs and figures to look for obvious trends and relations in the observed spot and futures prices. We then turn to analyse the relationship between the long- and short-term prices in more detail using the framework presented above.

A. *The data*

The analysis is based on historical spot and futures prices from Nord Pool covering the period from the opening of the futures market in September 1995 until the end of 2001. The futures data contained the closing price for each day of trading for all futures contracts traded. Although we had futures data for each day of trading, only the closing price on the last day of trading for each week was used in our analysis. The spot data used in the analysis contained spot prices for each hour of each day of the year. To consolidate the data, the spot price for a particular day was calculated by averaging the spot price for each hour of the day. To further consolidate the data, the daily spot prices are averaged over the week to get an average weekly spot price. Although we do not use the hourly spot price data explicitly, the average daily and weekly values are functions of the hourly spot price.

B. *Spot prices*

Fig. 7 shows the daily spot prices for all six years from 1996 to 2001. There is a lot of similarity in the spot prices for the years from 1997 to 2000. Although the prices vary, the shape of the graphs is similar in many respects. We clearly see the seasonal pattern with low prices during the summer when the demand is low, and high prices in the winter when demand is high (compare to demand in Fig. 2). The level of the spot prices in 1996 is much higher. The prices remain high throughout the summer, and increase even further in the fall. This is due to very low precipitation and inflow to the water reservoirs that year. The prices come back down again in the winter of 1997. Also in 2001 the prices are higher than what we see from 1997 to 2000. This can again be explained from lower inflow to the reservoirs. These observations illustrate how dependent the prices are upon the hydropower generation in the region. Another observations is that the price peaks in the beginning of 2001 occurs at the same time as the peak values for demand in the system. Hence, the current system runs into capacity problems on cold winter days with high demand. Actually, hourly prices above 1500 NOK/MWh occurred four times in the two first weeks of February 2001.

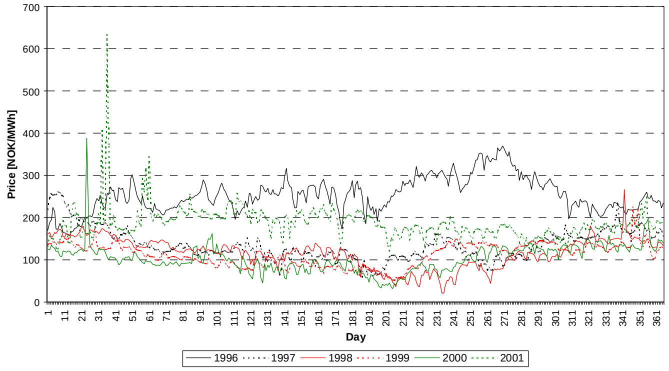

Fig. 7. Average daily prices in Nord Pool's spot market for years 1996-2001. Source: [5].

C. *Futures prices*

Fig. 8 shows prices for weekly futures contracts at the last day of trading, for delivery the following week. As can be seen from the graph, the futures prices follow the same trend as the spot prices, as we would expect for futures contracts with short time to delivery. It is reasonable to believe that the market expects the prices for the next week, as reflected in the futures prices, to resemble the spot price for the current week. The daily price fluctuations do not appear for the futures contracts though, since the prices shown are for weekly contracts.

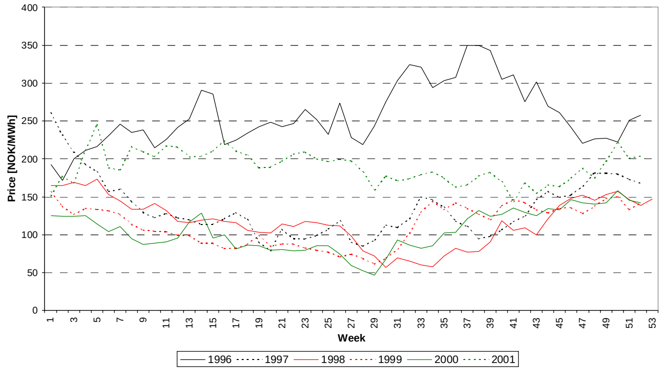

Fig. 8. Prices of a futures contract at the end of week t, for delivery week t+1, 1996 to 2001. Source: [5].

To further analyze the data, we compared the futures prices one week and one year ahead to the actual spot price in the delivery period (Fig. 9). For instance, for 1996 we recorded the futures prices with delivery one year ahead, in 1997, and plotted it together with the weekly spot prices for 1997. The futures price one week ahead is presented in the same way. We repeated this process for 1997 through 2000. As can be seen in the figure, the futures price one year ahead do not correspond very well with the actual spot prices in the delivery period. Looking closely at the graph, we see that both the futures and spot prices show a seasonal pattern. The long-term contracts with delivery one year ahead are season contracts[11], and the distinct jumps in this futures price curve occurs at changes between contracts (e.g. from Winter 1 to Summer). On average the futures price seems to overestimate the actual spot price in this period. However, in 2001, the futures price underestimates the actual spot price. There are several points of intersection between the two graphs. At these points, the futures price actually equaled the actual spot price for that week. In general however, the one-year ahead futures prices' ability to predict the spot prices is rather low, and there are large differences between the futures and spot prices in most of the period. For the contracts with delivery one week ahead, the fit is naturally much better, due to the much shorter time to delivery.

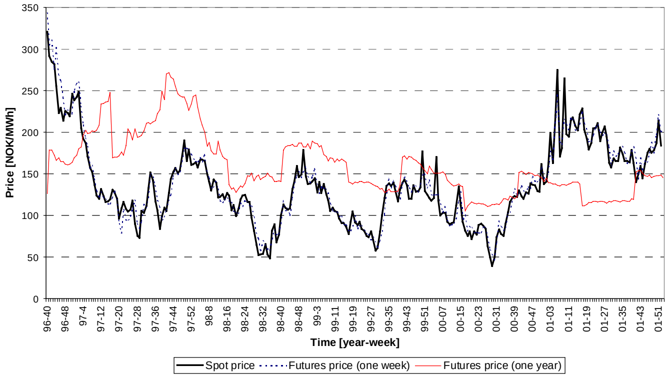

Fig. 9. Futures prices for last trading day before delivery and 52 weeks before delivery, compared to spot price in delivery week. Weekly values. Source: [5].

D. The risk premium in the futures market

We now try to estimate the observed risk premium in the Scandinavian electricity market based on the data presented above. From (2) we derive the following estimate for the risk premium, p_t, of a futures contract with holding period T:

$$p_T = \ln \frac{E_t(S_{t+T})}{F_{t,T}} \quad \rightarrow \quad \hat{p}_T = \ln \frac{F_{t+T-1,1}}{F_{t,T}} \qquad (3)$$

where $F_{t+T-1,1}$ is the price at the last day of trading for the futures contract with delivery in week $t+T$, which in turn is a good approximation for the spot price in the delivery week. In other words, we assume that the market participants in the long run have an unbiased prediction of the future spot price[12]. We calculated the estimate for the risk premium for futures contracts with 1 week, 4 weeks, ½ year and 1 year holding periods, assuming that the contracts are held until expiry. In our calculations we used all historical data that was accessible from the futures market. The results are show in Table 2. We see that the average risk premium is negative for all holding periods. The magnitude and standard deviation of the premium increases naturally with the length of the holding period. The p-values for the z-test show that we can reject the hypothesis that the futures price equals the expected future spot price with high significance for all holding periods. This is confirmed by the negative values for both the upper and lower limits of the 99 % confidence intervals for the risk premium. Our findings therefore lend support to the contango hypothesis for the electricity futures market in Scandinavia, i.e. there is a negative risk premium for holding a futures contract.

TABLE 2

STATISTICAL ANALYSIS OF THE RISK PREMIUM ESTIMATE, $\hat{p}_T$, FOR 1, 4, 26 AND 52 WEEKS' HOLDING PERIOD OF THE FUTURES CONTRACT

	1 week	4 weeks	26 weeks	52 weeks
Sample size	326	323	300	275
Mean	-0.015	-0.035	-0.085	-0.183
St. deviation	0.101	0.187	0.432	0.399
p-value, z-test[1]	0.9968	0.9996	0.9997	1.0000
CFI[2], up-limit	-0.001	-0.008	-0.020	-0.122
CFI[2], lo-limit	-0.030	-0.062	-0.149	-0.245

[1]The z-test tests for $p_T < 0$, given $p_T = 0$ as null hypothesis.

[2]CFI is the 99% confidence interval.

E. Discussion

The negative risk premium that we find in the futures price data is in line with our observation of the difference in flexibility on the supply and demand side of the electricity market, leaving the demand side with a higher incentive for hedging in futures contracts. However, there are most likely also other factors that can contribute to explain our findings. To further examine possible explanations we therefore look at the main source of power in the Scandinavian system – namely hydropower. As stated in section II the precipitation, and thereby the water level of the reservoirs, has a high degree of influence on the short-term prices of electricity in Scandinavia. However, the expectations about the spot prices far ahead into the future are probably based on assumptions of average reservoir levels. To investigate this further we plotted the average reservoir level in Norway along with the actual reservoir level in Fig. 10[13]. We also add the spot price and the one year ahead futures price. Looking closely at the graph, we see that the actual reservoir level is higher than the average for most of the period from 1998 through early 2001. High reservoir levels results in low spot prices, and during this period the spot price was below the futures price. In 2001, when the actual reservoir level falls below the average, we notice a sharp increase in the spot price. During most of 2001, the actual reservoir level is below the average and the

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[11] Nord Pool stopped the trading of seasonal futures contracts (with one year or more to delivery) after 1999, and replaced them with seasonal forward contracts. The one-year ahead futures prices with delivery in 2001 (traded in 2000) are therefore actually forward contract prices.

[12] Note that the estimate of p_T equals the return (in excess of the risk-free rate) on a futures contract purchased at time t and sold at the last day of trading (in week $t+T-1$). It also equals the return on a contract that is held throughout delivery, if the contractual amount is purchased in the spot market during the week of delivery. This is due to the price securing settlement in the futures market, as described in section II.

[13] More than 60% of the hydropower capacity in the current Nord Pool area is installed in Norway.

spot price is higher then the futures. Thus, the analysis of the inflow is helpful in explaining the deviation between the spot and futures prices. However, the deviations in reservoir levels can only be used as an explanatory factor for the behavior of futures contracts with long maturity. The change in reservoir level is very limited in the near future. Therefore, it cannot contribute to explain the negative risk premiums for the contracts with only 1 and 4 weeks to delivery.

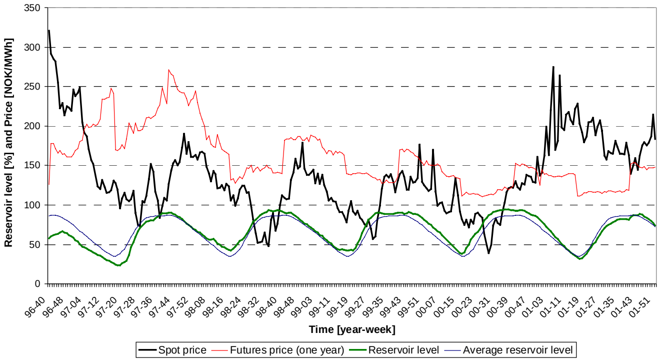

Fig. 10. Spot price, futures price one year ahead, average reservoir level (1990-2000) and actual reservoir level for Norway. Source: [5] and [13].

It is important to treat the results in this analysis with caution, as the data period is still limited to 6 years. A longer time period is usually used in similar analyses of futures prices for other commodities. The results for the z-test and confidence intervals in Table 2 also rely on a strong assumption of normality in the observed risk premiums. However, the existence of a negative risk premium can be stated with considerably higher significance than what was the case after the study in 1997.

V. CONCLUSION AND FUTURE WORK

Spot and futures markets for electricity have existed in the restructured Scandinavian electricity system for more than 6 years. The considerable history of prices makes it interesting to study the relationship between long- and short-term electricity prices in this market. Our analysis shows that the futures prices on average have been above the spot prices in the actual week of delivery, and we find significant evidence for a negative risk premium in the electricity futures market. Our results contradict to the findings in most other commodities futures markets, where the risk premium tends to be zero or positive. Physical factors like unexpected precipitation can contribute to explain parts of the observations. However, we also identify the difference in flexibility between the supply and demand sides as a possible explanation for the negative risk premium. In the future we will try to develop models that are better at capturing the dynamics between short and long-term prices in the electricity market. Our aim in the long run is to model how these prices influence the investments in new technology on the supply and demand side in the system, using methods for model aggregation from large-scale dynamic systems theory.

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VIII. BIOGRAPHIES

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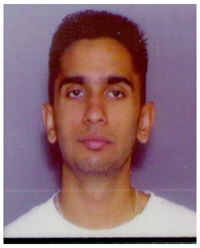

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