MARKET EFFICIENCY AT THE NORDIC POWER EXCHANGE, NORD POOL – AN ECONOMETRIC APPROACH

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The power industry in Romania is under the process of considering the establishing of a power exchange covering both Romania and potentially the neighbouring countries. Succeeding in developing a power exchange is dependent on several factors, including the principles of market efficiency. Considering the Nordic Power Exchange, Nord Pool being the first exchange of its kind as well as growing outside the Nordic countries, transferring experience from this area to Romania would be useful. Below it follows an analysis of the market efficiency at the Nordic Power Exchange, Nord Pool from an econometric point of view. In order to test market efficiency, two models are introduced – the Spot Price Model and the Consumption Model. If these models are able to predict the future spot price more accurate than the futures prices themselves, then the market is considered inefficient (in fact it rejects the weak form of market efficiency). Dependent on the accuracy of the models, they would also be highly useful in the risk management work and speculative trading at any power exchange by professional participants in the regional power markets.

1. Introduction

More and more power markets are deregulated and opened for free trade. The motivation for the deregulation is mainly increased competition and transparency as well as a more efficient market. The Nordic power market represented by the Nordic Power Exchange, Nord Pool is the first market of this kind, both covering the financial and the physical market (contracts with physical deliveries).

Historically the Nordic market has been represented by bilateral contracts, i.e. contracts between two parties in the market. These days more and more of the total trade is handled by Nord Pool, a total of 167 TWh in 2005 representing 67 percent of the total overall consumption [22].

Below an analysis of the market efficiency at Nord Pool follows. This is based on the publicly available information such as historical spot prices and futures prices of power through the operational years of Nord Pool, ref. below. Two models are presented, the Consumption Model and of the Spot Price Model.

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The analysis examines the forecasting accuracy of future prices as predictions of subsequent spot prices versus the forecasting ability of the Consumption Model and of the Spot Price Model based on the publicly available information at Nord Pool.

In the case these models outperform the futures markets' ability to forecast the subsequent spot price, the market according to statistical theory is considered inefficient (in fact it rejects the weak form of market efficiency) [24]. This is the basis for the analysis. This is one of the listed references testing market efficiency enclosed.

2. Data and methodical problems

Nord Pool provides spot prices on an hourly basis from the operational start in 1995 as well as daily closing prices for each day of trading. The same is the situation for the futures contracts.

The daily system price of Nord Pool used as the reference price when settling financial contracts is found by calculating the average of the 24 hours spot prices for each day. The contracts termed F1, F4 and F12 are futures contracts with 1, 4 and 12 week(s) trading period.

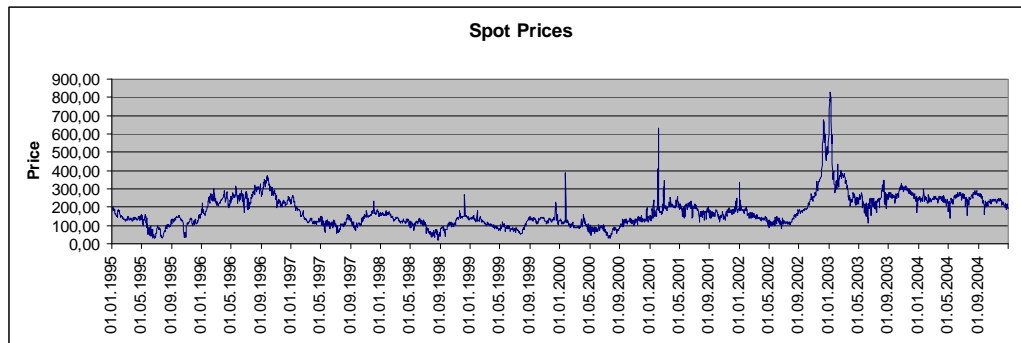The figure below shows the weekly system price from 1995 to the end of 2004.

Fig. 1. Weekly system price in NOK/MWh from 1995 to 2004
Source: [22].

Fig. 1. shows both high volatility of the system price as well as seasonal patterns. The seasonal patterns are partly a result of the use of power for heating mainly in Norway and Sweden [22].

Futures prices.

As mentioned above, three different futures contracts will be used in the analysis, F1 (1 week), F4 (4 weeks) and F12 (12 weeks). The two first contracts will look into the relative short term relationship between the spot contracts and

the futures contracts while the last contract will look into the relationship in the relative long run.

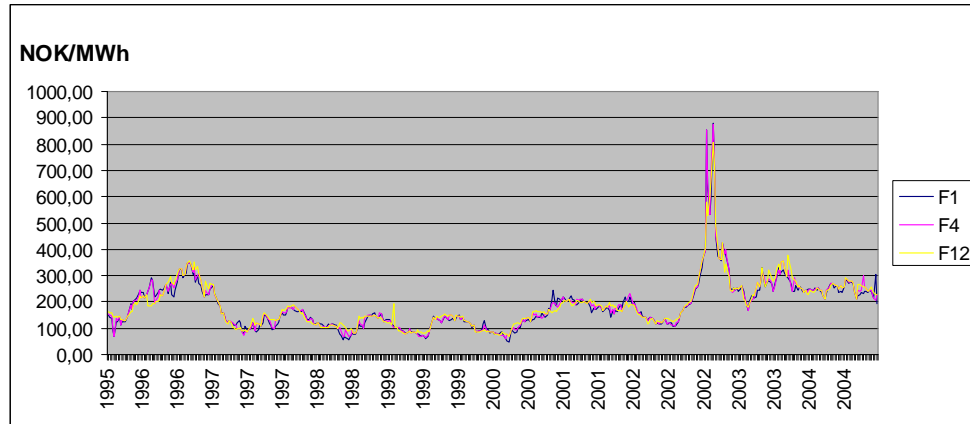The figure below shows the relationship between the futures contracts defined above.

Fig. 2. The different futures contracts, NOK/MWh for the period from 1995 to 2004.

F1= 1 week futures contracts. F4= 4 weeks futures contracts. F12=12 weeks future contracts.
Note: Weekly observations.
Source: Input data from Nord Pool [22].

Fig. 2. shows the same seasonal variations for the futures prices compared to the system price.

The consumption data contains daily observations of total consumption in Denmark, Finland, Norway and Sweden from 1997.

The figure below shows the total daily consumption of the region based on weekly observations from 1997 to 2004.
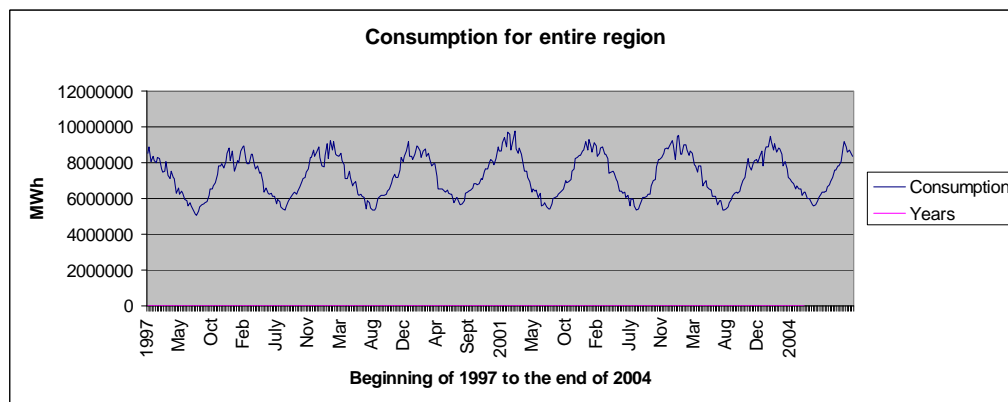
.

Fig. 3. Consumption of power in the Nordic region from 1997 to 2004, MWh.
Source: Input data from Nord Pool [22].

The consumption data shows a clear pattern with increasing values towards January and February for then to decrease towards mid summer. This is partly a result of the use of power for heating mainly in Norway and Sweden [22].

3. Consumption data as a predictor of spot prices

This section will look at the possibility of forecasting the future spot price using the available data on consumption. The data used is the weekly consumption in the Nordic region from 1997 to 2004 and the average weekly system price for the same period of time.

The consumption itself can be modelled reasonably well by a cosine function, which explains around 92 percent of the variation. The highest R^2 (coefficient of determination) is found at the top of the cycle in week 2 and at the bottom in week 28.

If dummies (D) for each year are added, R^2 increases to 94 percent. The model is presented below.

$$C_t = \alpha + \beta CosCycle + D1997 + D1998 + D1999 + D2000 + \varepsilon_t,$$
$$\text{where } CosCycle = \cos(2\pi(week - 2)/52)$$

The results from the above formula is presented in the below table.

Table 1.

The results from the consumption model, MWh.

α	β	D 1997	D 1998	D 1999	D 2000	DW	R2
7380178	1573125	-369831.9	-2 23365.3	-194892.5	-114650.7	1.02	0.93
(333)	(71.12)	(-7.45)	(-4.53)	(-3.92)	(-2.30)		

Note: D represents dummies for each year, DW the Durbin Watson test.

Source: Input data from Nord Pool [22].

The Augmented Dickey Fuller tests (*ADF*-tests) of residuals (with a constant, a constant and trend and seasonal) all reject the hypothesis of non stationarity at the 1 percent confidence level.

Fitting the residuals to an AR(3) model (third-order autoregressive disturbance model) gives a very good result with a *Ljung-Box* statistic (method for testing autocorrelation) clearly indicating that the residuals from this model can be taken as pure noise.

The result of the tests are presented in the below table.

Table 2

Residuals of consumption as cosine cycle modelled as AR (3), MWh.

	Coef	SE Coef	T-statistics	P-value
AR 1	0.470389	0.043595	10.78992	0.00
AR 3	0.120241	0.043634	2.755684	0.00

Note: If the P-value is less than 0.05, then the coefficiency is significantly different from 0.

Source: Input data from Nord Pool [22].

The above table gives the following equation.

$$C_t = \alpha + \beta CosCycle + D1997 + D1998 + D1999 + D2000 + 0.47Z_{t-1} +$$

$$+0.12Z_{t-3} + \varepsilon_t$$

where $CosCycle = \cos(2\pi(week-2)/52)$.

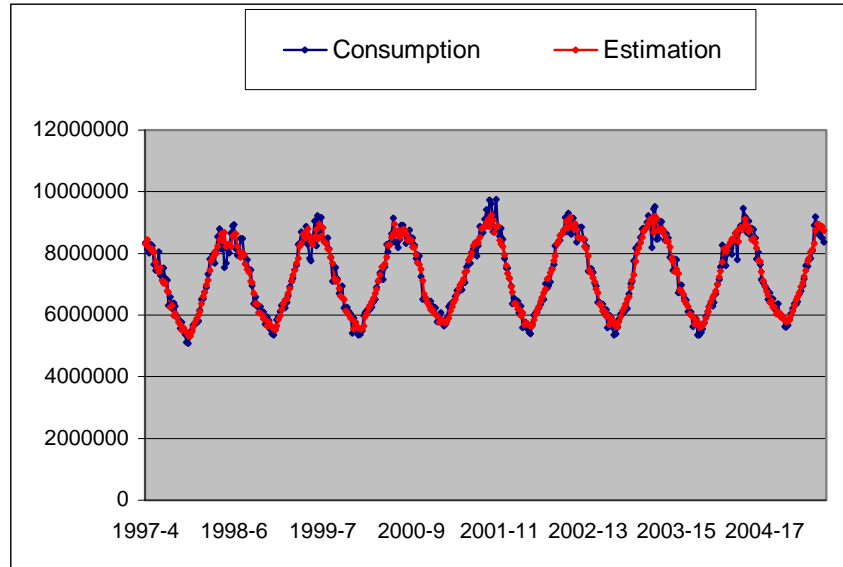The real and estimated consumption data is presented in the below figure.

Fig. 4. Real and estimated consumption, MWh
Source: Input data from Nord Pool [22].

The model for consumption with cosine function AR terms on the residuals has $R^2 = 95$ percent and $DW=1.95$.
Even though the consumption can be modelled quite well, the forecasting ability when estimating the future system price is rather low. The level of the consumption only explains around 14 percent of the variance in the system price. Adding lags does not improve this and the lags are not statistically significant.

On the other hand, the consumption explains 17 percent of the variation in the log system price, and by adding a linear trend it increases to 56 percent. The trend is not perfectly linear, but it moves in steps for each year. Considering that the trend adds much value in terms of the explained variance as well as the parameter being positive, means that the increase in the system price does not come as a result of increased consumption.

This is reflected in the below equation.

$$Log(S_t) = \alpha + \beta_1 C_t + \beta_2 Year + \varepsilon_t,$$

where the variable *Year* refers to year at time t (e.g. 1997, 1998 etc.)

The result of the above equation is presented in the table below.

Table 3

Log **spot price modelled by consumption and linear yearly trend, NOK/MWh**.

α	β1	β2	DW	R2
-243.45 (-18.52)	0.000000138 (10.65)	0.13 (18.81)	0.11	0.55

Source: Input data from Nord Pool [22].

Substituting the actual consumption (*Ct)* by the estimated consumption from the model above, the yields are presented in the table below.

Table 4

Log spot price modelled by estimated consumption and linear yearly trend, NOK/MWh.

α	β1	β2	DW	R2
-249.84 (-19.02)	0.000000135 (10.2)	0.13 (19.31)	0.15	0.56

Source: Input data from Nord Pool [22].

As a result of the above, the full model for forecasting the log spot price using consumption and a trend is as follows.

$$Log(S_t) = \text{-}249.84 + 0.000000135 EstC_t + 0.13 Year + \varepsilon_t$$

where
$$EstC_t = 7380178 + 1573125 CosCycle \text{-} 369831.9 D1997 \text{-}$$
$$\text{-}223365.3 D1998 \text{-} 194892.5 D1999 \text{-} 114650.7 D2000 + 0.47 Z_{t-1} + 0.12 Z_{t-3} + \varepsilon_t$$

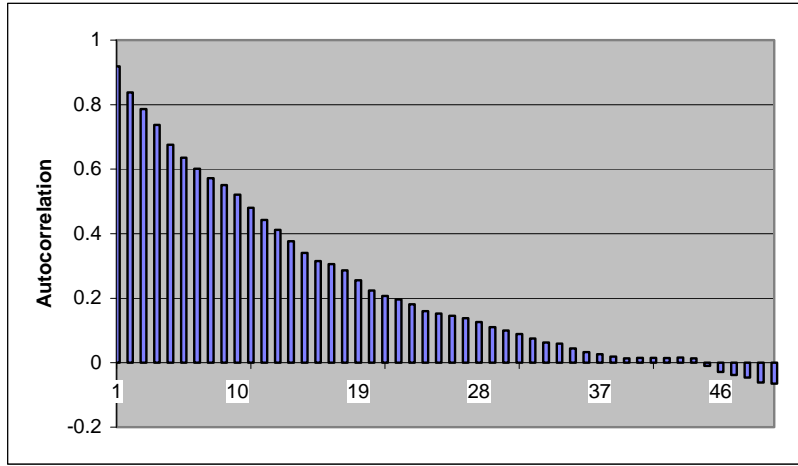The *DW* value is very low, indicating positive autocorrelation.

Fig. 5. Autocorrelation plot of residuals from estimation of the log system price as a function of
estimated consumption and yearly trend, NOK/MWh.
Source: Input data from Nord Pool [22].

The autocorrelation plot of the residuals has an exponential and relatively fast decay towards zero, indicating an AR-model. *ADF* tests reject the null hypothesis on non-stationarity.

Fitting the residuals to an AR(1) model gives the following results.

Table 5

Residuals from estimation of the log system price as function of estimated consumption and a yearly trend fitted to an AR(1) model, NOK/MWh.

	Coef	SE Coef	T-statistics	P-value
AR 1	0.923190	0.018779	49.16020	0.00

Note: If the P-value is less than 0.05, then the coefficiency is significantly different from 0.

Source: Input data from Nord Pool [22].

The final equation for predicting the log spot price is presented below.

$$Log(S_t) = -249.84 + 0.000000135 EstC_t + 0.13Year + +0.92Z_{t-1} + \varepsilon_t$$

where

$$EstC_t = 7380178 + 1573125 CosCycle - 369831.9D1997 - \\ -223365.3D1998 - 194892.5D1999 - 114650.7D2000 + 0.47Z_{t-1} + 0.12Z_{t-3} + \varepsilon_t$$

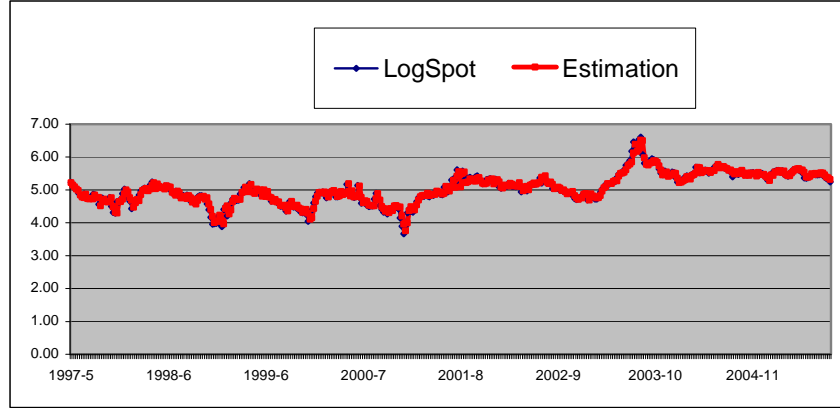The result of the equation is presented in the figure below.

Fig. 6. Plot of estimated value from equation against the real log spot values, NOK/MWh.
Source: Input data from Nord Pool [22].

Hence for predicting the log spot price one week from now the equation is as follows.

$$Log(S_{t+1}) = \textit{-249.84+0.000000135EstC}_{t+1}\textit{+0.13Year+} + 0.92Z_{t-1} + \varepsilon_t$$

where

$$EstC_{t+1} = 7380178 + 1573125[Cos(2\pi(week-2)/52)]\text{-}369831.9D1997\text{-}$$
$$\text{-}223365.3D1998\text{-}194892.5D1999\text{-}114650.7D2000 + 0.47Z_{t-1} + 0.12Z_{t-3} + \varepsilon_t$$

The week is the actual week number at time t+1 and D1999 and D2000 can take the values 0 or 1.

4. Today's spot price as predictor of future spot price

Historic price data from Nord Pool may contain interesting information when forecasting future spot prices. To limit the variance the log system price is calculated.
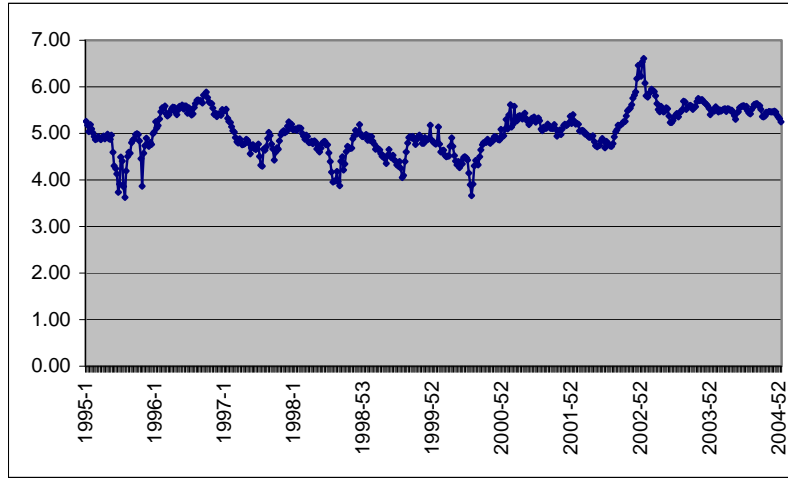The result of the calculations are presented in the below figure.

Fig. 7. Plot of average weekly system price, NOK/MWh.
Source: Input data from Nord Pool [22].

The autocorrelation plot of the series shows that it is non stationarity. It is presented in the below figure.
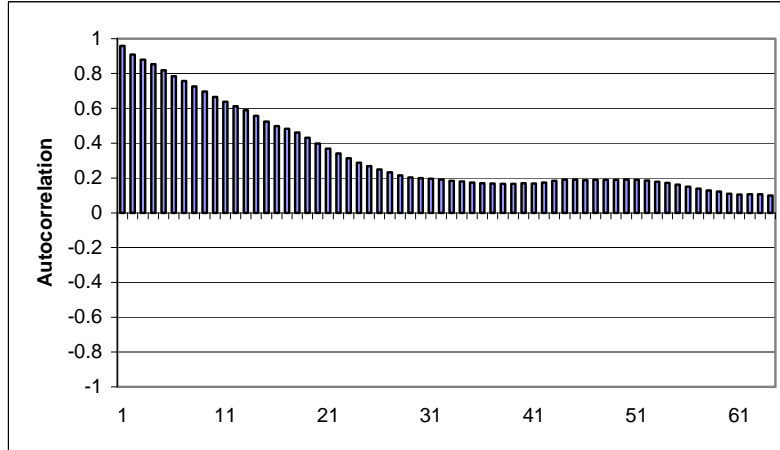

Fig. 8. Autocorrelation plot of the average weekly log system price, NOK/MWh.
Source: Input data from Nord Pool [22].

A common approach to achieve stationarity is to use 1st differences (instead of the original time series $- X_t$, the new time series, $X_t - X_{t-1}$ is used).
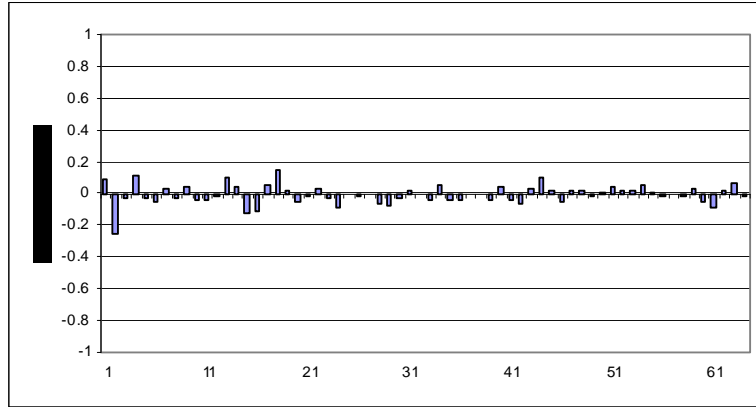
Fig. 9. Autocorrelation plot of difference average weekly log system price, NOK/MWh.
Source: Input data from Nord Pool [22].

This shows that the new series of differences is stationary, supported by the *ADF* tests on the differences which clearly reject the null hypothesis of non starionarity as well.
Fitting the series to an AR(2) model is illustrated in the below table.

Table 6.

Diff. avg. weekly log system price as an AR(2)-model. NOK/MWh.

	Coef	SE Coef	T-statistics	P-value
AR 1	0.111	0.043	2.56	0.01
AR 2	-0.259	0.043	-5.97	0.00
Residuals	SS	8.372		
	MS	0.130		

Note: If the P-value is less than 0.05, then the coefficiency is significantly different from 0.
Source: Input date from Nord Pool [22].

Both AR 1 and AR 2 are statistically significant, and the model gives a good fit as indicated by *P*-values higher than 0.05 using 5 percent confidence level.
An alternative to using differences when trying to model the system price is to find a deterministic trend around which it fluctuates. Once again, one can imagine a cosine trend being used, with its top in the winter season and bottom in summer or mid year. The plot log system price does not fit this curve exactly, but resembles this pattern to some extent.

LogSysPrice=$\alpha + \beta$ *YSeas* ,

where *Yseas* is the seasonal pattern during a year (the cosine curve, similar to the one in the previous section describing consumption data).

Table 7

Results from log system price as a function of yearly seasonal pattern, NOK/MWh.

	Coef	SE Coef	T-statistics	P-value
Constant	5.044	0.019	253.02	0.00
Yseas	0.211	0.028	7.51	0.00

Note: If the P-value is less than 0.05, then the coefficiency is significantly different from 0.
Source: Input data from Nord Pool [22].

An autocorrelation plot of the residuals from this regression shows non stationartiy. *ADF* tests also support non stationarity.
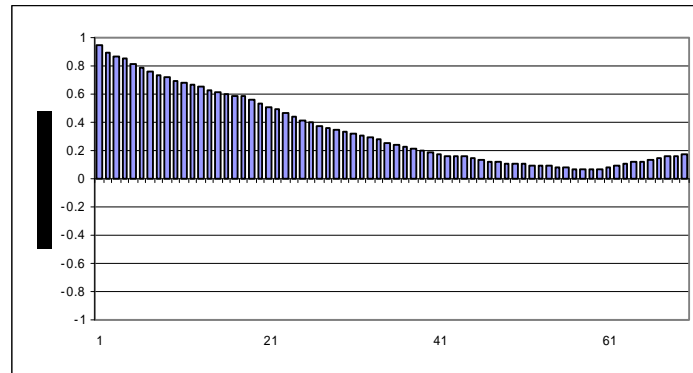The result of these tests are presented in the below figure.

Fig. 10. Autocorrelation plot of residuals, NOK/MWh.
Note: Number of lags on the horizontal axis.
Source: Input data from Nord Pool [22].

The residuals are then differentiated to achieve stationarity and fitted into the below AR(2) model presented in the below table.

Table 8

Residuals from regression fitted to an AR(2)-model, NOK/MWh.

	Coef	SE Coef	T-statistics	P-value
AR 1	0.089	0.043	2.071	0.039
AR 2	-0.280	0.043	-6.499	0.000
Residuals	SS	8.13		
	MS	0.13		

Note: If the P-value is less than 0.05, then the coefficiency is significantly different from 0.
Source: Input data from Nord Pool [22].

Also here both AR 1 and AR 2 are statistically significant.

Fitting the differentiated residuals of the reduced sample regression to an AR model gives approximately the same results as for the model that included the full sample.

Results of the model which estimated the log system price as a function of a yearly cycle represented by a cosine function and which fitted the residuals of an AR model are presented below.

$$X_t = \alpha + \beta \cos(2\pi t / 52) + Z_t$$

where t represents the week number and

$$\Delta Z_t = \phi_1 \Delta Z_{t-1} + \phi_2 \Delta Z_{t-2} \Rightarrow Z_t = Z_{t-1} + \phi_1(Z_{t-1} - Z_{t-2}) + \phi_2(Z_{t-2} - Z_{t-3})$$

Thus the full equation is:

$$X_t = \alpha + \beta \cos(2\pi t / 52) + Z_{t-1} + \phi_1(Z_{t-1} - Z_{t-2}) + \phi_2(Z_{t-2} - Z_{t-3})$$

This can be written as:

$$X_t = \alpha + \beta \cos(2\pi t / 52) + (1 + \phi_1)Z_{t-1} + (\phi_2 - \phi_2)Z_{t-2} + \phi_2 Z_{t-3}$$

The regression and the AR model (based on residuals of the regression) gave:
$$\alpha = 5.05$$
$$\beta = 0.22$$
$$\phi_1 = 0.08$$
$$\phi_2 = -0.26$$
which gives the final equation:
$$X_t = 5.05 + 0.22 \cos(2\pi t / 52) + 1.08 Z_{t-1} - 0.36 Z_{t-2} - 0.26 Z_{t-3}$$
So for predicting the average log system price for next week the equation is:
$$X_{t+1} = 5.05 + 0.22 \cos(2\pi(t+1) / 52) + 1.08 Z_t - 0.36 Z_{t-1} - 0.26 Z_{t-2}$$
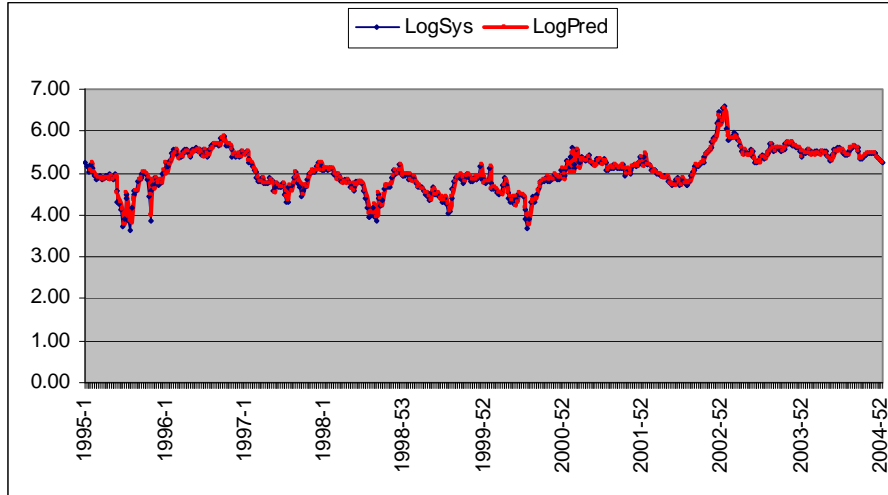
Fig. 11. Predicted plotted log system price vs. real log system price, NOK/MWh.
Source: Input data from Nord Pool [22].

5. Comparing the Spot Price Model and the Consumption Model with the future price

In order to make a comparison between the Spot Price Model and the Consumption Model with the future price, series of predicted values are generated from the Consumption Model and the Spot Price Model above. To simplify the calculations, only the F1 and F4 contracts are used. The comparisons are made using mean square errors (*MSE*).

The F1 and F4 contracts at Nord Pool represent the week which is 2 weeks and 5 weeks ahead, respectively. As a result of this, the mean square errors are compared to the mean square error of the 2 and 5 weeks from the two models.

$$MSE_F = \frac{\sum (S_{t+T} - F(1)_t)^2}{n_F}$$, where T=1 or 4 and n_F is the size of the sample

$$MSE_{SPM} = \frac{\sum (S_{t+T} - P_{SPM}(T)_t)^2}{n_{SPM}}$$, where $P_{SPM}(T)_t$ is predicted spot price T periods ahead and T=2 or 5

$$MSE_{CM} = \frac{\sum (S_{t+T} - P_{CM}(T)_t)^2}{n_{CM}},$$ where $P_{CM}(T)_t$ is predicted spot price T periods ahead and T=2 or 5

Table 9.

MSE for the Spot Price Model, Consumption Model and futures prices, NOK/MWh.

	F(T)	SPM(T+1)	CM(T+1)
T=1	0.026	0.028	0.053
T=4	0.050	0.060	0.041

Note: Prices are log prices.

Source: Input data from Nord Pool [22].

The above table shows that the F1 futures contract outperforms both the Spot Price Model and the Consumption Model. The Consumption Model seems to come close to the F1 futures price contract. When it comes to the F4 futures contract, it is marginally outperformed by the consumption model.

6. Conclusions

According to statistical theory, market efficiency can be tested by examining the relative accuracy of the forecasting ability of the futures prices compared to established and well proven forecasting methods. If a model more accurate than the futures market exists, the market is considered inefficient [24].

More tests would have to be performed to conclude whether or not the future market at Nord Pool is efficient according to the above statement. However, the Consumption Model outperforms the F4 futures contract giving an indication that the market is inefficient.

On the other hand, the Spot Price model, the Consumption Model related to the F1 futures contracts and the Mean Square Errors comparison between the futures price as a predictor of subsequent spot price and the spot price itself as a predictor of future spot price, do not reject the hypothesis of market efficiency at Nord Pool.

The analysis of the forecasting error of the futures prices shows that all the three different futures contracts on average tend to overestimate the spot price at delivery, i.e. all means are statistically significant. The standard deviations and the range between the minimum and maximum values are in all cases very high. The fact that the sample includes the dramatic situation of winter 2002/2003 where the futures prices greatly underestimated the subsequent spot price, means that the mean values of more normal years are even higher than what was found above.

Hence, the mean errors seam unreasonably high and the futures price appears to be a relative poor forecast of subsequent spot.

Even though the above analyses indicate market inefficiency at the Nordic Power Exchange, Nord Pool – it is only to a limited extent. The market is steadily in development with more and more of the total power traded, handled by the exchange. All in all, benefits that the Nordic Power Exchange, Nord Pool offers to the participants of the power market far exceeds the indicated market inefficiency. Most participants would agree that the market being both liquid and transparent it represents an excellent tool for both risk management and speculative trading.

R E F E R E N C E S

[1] *Anoniou, A. & Forster*, A.J., Short-Term and Long Term Efficiency in Commodity Spot and Futures Markets, Financial Markets, Institutions and Instruments, 1994.
[2] *Beck. S.E,* Cointegration and Market Efficiency in Commodities Futures Markets, Applied Economics 26, 1994.
[3] *Burn, D.W.*, Modelling Prices in Competitive Electricity Markets, Wiley Chichester.
[4] *Cambell, J.Y. Lo A.W. and MacKinlay A.C.* (1997), The Econometrics of Financial Markets, Princeton Univeristy Press, 2004.
[5] *Chance, D.M.*, Derivatives and Risk Management – fifth edition, Hartcourt College Publishers, 2001.
[6] *Fama, F.*, Efficient Capital Markets: A Review of Theory and Empirical Work, Journal of Finance 25, 1970.
[7] *Fama, E.F. and French, K.R.*, Commodity Futures Prices: Some evidence of forecast power, premiums and the theory of storage, The Journal of Business 60, 1987.
[8] *Fontenbery, T.R. & Zapata, H.O.*, An evaluation of Price Linkages Between Futures and Cash Markets for Cheddar Cheese, Journal of Futures Markets 17, 1997.
[9] *Giles, D.E.A. & Goss, B.A.*, 'The predictive Quality of Futures Prices with an Application to the Sydney Wool Futures Market", Australian Economic Papers 19, 1980.
[10] Greene, W.H., Econometric Analysis, Prentice-Hall International, 2000.
[11] *Haigh, M.S.*, Cointegration, Unbiased Expectations, and Forecasting in the BIFFEX Freight Futures Market, The Journal of Futures Markets 20, 2000.
[12] *Hope, E. & Strøm S.*, Energy Markets and Environmental Issues. Scandivavian University Press, 1992.
[13] *Hull, J.C.*, Introduction to futures and options markets, New Jersey: Prentice-Hall, 1998.
[14] *Johnsen, T.*, The Pricing of Electricity Futures: Empirical Tests for Market Efficiency at Nord Pool, Working Paper, 2003.
[15] *Kellard, N., Newbold, P., Rayner, T. and Ennew, C.*, The Relative Efficiency of Commodity Futures Markets, Journal of Futures Markets 19.
[16] *Kenyon, D., Jones, E. and McGuirk, A.,* Forecasting Performance of Corn and Soybean Harvest Futures Contracts, American Journal of Agricultural Economics 75.
[17] *Kofi, T.A.*, A Framework for Comparing the Efficiency of Futures Markets, American Journal of Agricultural Economics 55, 1973.
[18] *Lai, K.S. & Lai M.*, A Cointegration Test for Market Efficiency, The Journal of Futures Markets 11, 1991.
[19] *Leuthold, R.M.*, Re Prices Performance on the Life Beef Cattle, American Journal of Agricultural Economics 56, 1994.

[20] *Lucia, J.L. & Schwartz, E.S.*, Electricity Prices and Power Derivatives, Evidence from the Nordic Power Exchange, forthcoming Review of Derivatives Research, 2001.

[21] *Maddala, G.S.*, Introduction to econometrics 3rd edition, John Wiley & Sons Ltd, 2001.

[22] Nord Pool ASA "The Nordic Spot Market", published on www.nordpool.com.

[23] *Poon, S.H.* A Practical Guide to Forecasting Financial Market Volatility, Chichester Wiley, 2005.

[24] *Rausser, G.C. & Carter, C*., Futures Market Efficiency in the Soybean Complex, The Review of Economics and Statistics, 1982.

[25] *Wolfers, J. & Zitzewitz, E.*, Prediction Markets in Theory and Practice, Working paper nr. 12083, National Bureau of Economic Research, Cambridge Ma 02138, 2006.

[26] *Wolfers, J. & Zitzewitz, E*., Five Open Questions about Prediction Markets, Centre for Economic Policy and Research, London, 2006.