THE EFFICIENCY OF THE FUTURES MARKET IN THE DEREGULATED ELECTRICITY INDUSTRY

by

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Abstract

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The paper addresses the efficiency of the futures market in the deregulated electricity industry. It studies a sample of European countries to find which factors improve market efficiency and contribute to an increase of a social welfare. Based on research the paper works out recommendations and policy implications for Ukraine to prepare the optimal environment for launching its own futures market as a part of deregulation process conducted in the electricity industry.

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I would like to express special gratitude to my thesis advisor Tom Coupe, who spent a lot of time editing, tuning and finalising my paper.

GLOSSARY

Base Load	The load of current stream 24 hours a day
Basis	The difference between spot and futures price
Deregulation	Process of restructuring the state-owned monopoly to competitive market
DGP	Data Generating Process Technique used in econometrics
EMH	Efficient market hypothesis
Futures	Standardized contracts which possess the obligation to buy or sell products at some future date, while price, terms and conditions are set up during the contract initiation
Overlapping	The situation when data periods overlap and cause biased results in regression
Peak Load	The load of current stream during peak hours (7-9 p.m.)
VECM	Vector error correction model

Chapter 1

INTRODUCTION

The deregulation of the electricity industry, which took place in many countries throughout the world, is going to start in Ukraine. By deregulation we mean separation of major electricity production and marketing activities, such as generation, transmission, distribution and retailing of electricity (Bergman et. al. 1999) and privatizing them by going public. Obviously, as the common experience shows (Energy Information Administration. Washington D.C., 2000) deregulation brings more volatility to prices and creates uncertainty, therefore produces risk in the industry. One of the possible remedies for price risk is the introduction of the electricity futures market. This market helps participants hedge their electricity price risks. However, the organization of the futures market requires quite large sunk costs. Moreover, even after the market is launched, the social costs associated with futures trading increase substantially whenever the market happens to be inefficient (Stein 1986). In addition, when inefficient, the market produces additional cost burden on hedgers (Krehbiel & Adkins 1993). Therefore, there is a good reason to assess the degree of market efficiency. The main goal of this paper is to estimate the relative efficiency of the countries that already had deregulated their electricity industries. Such analysis will be helpful for Ukraine, because it shows how "useful" futures markets are in competitive electricity industry. If it happens that most of the data supports the evidence of strong inefficiency, then it is not clear whether it is a good point to start the futures market in Ukraine and let the social costs of inefficiency be passed through to the consumers. The significance of the paper is highly correlated with the success of the electricity market deregulation in Ukraine. The Ukrainian government and the National Electricity Regulatory Commission are to implement the pilot project of futures trading between the market participants. To say more, research studies are being held to find out what the necessary conditions and terms of introducing electricity futures are. One of the urgent tasks the specialists are considering is the costs and benefits of launching the futures electricity contracts in Ukraine. The analysts try to answer the question of the possible consequences of setting up such a market. It could happen that the costs to start up the project would overstate the benefit of reduced price risk for participants. Such a situation is possible in case when the futures market tend to be inefficient. Inefficiency would certainly add sufficient cost to hedgers and substantially decrease the overall social utility of the project. Economists estimated the efficiency of the agricultural products futures market in China (Wang and Ke, 2002), energy futures markets in the USA (Newbold et al., 1999), market for various commodities in UK (Kellard et al., 1999), US energy products (Peroni, 1998), natural gas market in Algeria (Mazighi, 2003), US electricity futures market (Bai et al., 2000). However, as far as I know, noone tried to estimate the efficiency in electricity futures market for Nordic countries and Germany. It could probably happen that electricity futures markets are strongly inefficient by nature. If that is the case, then obviously Ukraine is not ready to set up the futures market for electricity. The developed countries could dare to launch the market that potentially would bring more costs than benefits for market participants because they were the first to deregulate their electricity industries and they did not have predecessors and experience. The inefficiency does not necessarily imply that the futures markets for electricity are not needed in Ukraine at all, but just that the question should be investigated further to derive reasonable conditions suitable for the market to exist. Finally, the inefficiency could obviously give the wrong incentives to speculators, meaning, that knowing about the possibility to earn abnormal profits, speculators would certainly engage in a large-sum manipulations and, what is even more important, destabilize the whole industry.

There exist a substantial number of papers that address the futures market efficiency issue. However, most of the papers deal with efficiency as an objective feature of the market not as the quantitative measure of market "usefulness". What I am going to do is to estimate the degree of futures market efficiency rather than to state whether it is efficient or not. The so-called relative measure of efficiency, first employed by Kellard et. al. (1999) will make it clear whether the market is *relatively* efficient. Moreover, this efficiency measure will show what fraction of the inefficiency of the market is explained by the poor ability of the futures prices to forecast the spot prices. Strictly speaking, it is considered that market efficiency is explained by perfect predictive power of prices. For some commodities the market was found to be inefficient not because of the futures weak predictive power, but rather due to some additional reasons, like risk and time premiums, transportation costs, unevenly spaced contracts etc. (Kellard et al., 1999). I am interested in calculating the relative measure of efficiency for electricity futures in sample countries and calculating the degree of the futures predictive power. Even if it happens that most of the markets show the signal of complete inefficiency, still there is a room for thinking futures having a good predictive power. (McNown, 1998). In other words, they would tend to reduce the risk of hedgers.

My paper is unique in a sense of estimating the efficiency measure for the electricity market that has never been done before with the countries I do. The analysis has been done for USA, China, Algeria, UK. I am going to assess Germany and Nordic countries (Sweden, Finland, Norway and Denmark). Secondly, I employ a technique used by Kellard et al (1999). To be more precise, I would like to incorporate econometric models that will solve for endogeneity, simultaneity bias and cointegration problems. This method is based on the assumption that market efficiency requires the equivalence of data generating process (DGP) for spot and lagged futures series (Engle and Granger, 1987). The detailed exposition to the model specification is in the main body of the paper. I will use the different holding period for futures and the latest data available. The originality of the paper stems from the attempt to combine all the best methods used in different papers to assess the futures market for electricity. McNown et al. (1996) compared different methods of testing for efficiency and tested it for the U.S. energy products. I will perform informative test for the European countries mentioned earlier.

The remainder of the thesis is organized as follows. Next section deals mostly with literature review. It encompasses the main ideas and conclusions of several major papers on the subject. Literature review reveals not only the contributions of each author to the idea of market efficiency, but also the controversial issues existing on the matter. The third section exposes theoretical model and econometric foundations of the research. It includes the model itself, theoretical background, explanations of the variables, regressions, formulas and sketches the mathematical framework of the paper. The fourth section of the research is devoted to the data used in the paper and empirical results obtained. The data is characterized by structure, sources, period and relevance to the paper. Interpretation and description of results are organized to help easy comprehension. The last section of the paper draws conclusions, compares to the previous results from the literature, provides policy recommendations and points the direction for further research.

Chapter 2

LITERATURE REVIEW

The idea of the paper is based on the efficient market hypothesis (EMH). One of the assumptions of the hypothesis is that "prices of the securities in financial markets fully reflect all available information". (Mishkin,2000). EMH says that people are forming rational expectations using the best available information. This large hypothesis can be on our purpose reduced to a joint hypothesis, which addresses the assumption that people are, in a broad sense, endowed with rational expectations, risk neutral and concludes that futures prices are the unbiased predictor of the spot prices, therefore, nobody can make monopoly profits (Taylor, 1995).

In general there are three main ways to test for the efficiency of the futures market: weak-form test, in which the data contains only historical information; semi-strong test including all publicly available information and strong-form efficiency test, where prices include all the relevant information, not only public. The weak-form test was very popular in early papers, because other tests – semi-strong and strong – are very difficult to perform. Fama (1987) developed the expected return model, random-walk model and sub-martingale model, all of those very extensively used in early works.

As argued by Sten (1986), efficiency tests do not result in any specific degree of efficiency, therefore lacking to provide some basis for comparison of futures markets for different commodities. Moreover, for many years of research there were indicated several factors that cause rejection of the efficiency hypothesis even if the market is efficient. These are risk premium (Krehbiel & Adkins, 1993), inability of futures prices to incorporate all market information (Beck, 1994), inefficiency of market participants (Kaminsky and Kumar, 1990), the lack of efficiency for markets, for which storage and transportation returns are nonstationary (Fortenbery and Zapata, 1993).

Here is the view of the literature on the methodology itself.

We know EMH states that market agents use all publicly available information to make their prediction of the future spot price (Kellard et. al., 1999):

$$e_t = S_t - E_{t-1}(S_t), \tag{1}$$

where e_t is a forecast error;

S_t – the natural logarithm of the spot price at time t;

$E_{t-1}(S_t)$ – expectation of the spot price for the moment t, at time t-1.

The risk neutrality and zero transportation cost assumptions make it clear that the market participants would push the futures price to equal the expected spot price. However, if some agents are risk-averse, they would probably demand risk premium, therefore yielding the following equation (Kellard, 1999):

$$F_{t-1} = E_{t-1}(S_t) - v_{t-1}, \tag{2}$$

in which v_{t-1} stands for varying risk premium (not necessarily zero). Frenkel (1981) explained this premium as a measure of the noise in F_{t-1}, in other words, a proxy for the future expected spot price. Combining equations (1) and (2) would yield a kind of efficiency testing model (Kellard, 1999):

$$S_t = \alpha + \beta F_{t-1} + e_t + v_{t-1} \tag{3}$$

In order for the EMH to be satisfied we should have $\alpha=0$ and $\beta=1$. Moreover, the $e_t + v_{t-1}$ component should be stationary. Early papers on the futures markets efficiency employed the usual OLS methods in regressing spot prices on the futures prices lagged by the chosen holding period (See 3). Several researchers, like Gray (1970), Schechtman (1983), Goss (1981), estimated this model specification by simple OLS for a range of commodities and obtained non-significant and biased results. A linear regression model was used by Birgman et al. (1983) to test for the efficiency of agricultural futures markets, such as wheat, corn and soybeans, all traded on the CBOT. Maberly

(1985) and later Shen and Wang (1990) claimed the results to be not reliable because of inappropriate model for non-stationary series. The reason is that with I(1) series test statistics do not follow the conventional distribution theory (Elman and Dixon, 1988). That is why stochastic properties of the time series should be addressed very seriously. Almost all papers on efficiency of the commodity futures markets used to apply the Dickey and Fuller (1979) technique to check for the presence of stationarity. Several papers, like Quan (1992), Serletis (1994), Crowder and Hamed (1993), Schwarz and Szakmary (1994) proved energy futures price series to be nonstationary[1]. Most empirical papers show the evidence for spot and futures prices in commodity and financial markets to be integrated. Often, the prices are integrated of first order, meaning they should be once differenced to become stationary.

What is more crucial, even if the S_t and F_{t-1} are separately I(1) they could jointly give the stationary linear combination, then we consider time series to be cointegrated (Peroni, 1998):

$$S_t - \alpha - \beta F_{t-1} = \mu_t \tag{4}$$

Quan (1992), Crowder (1993), Schwarz (1994) found the evidence of cointegration between spot and futures time series of energy products[2].

Cointegration gives us two main implications: 1) OLS estimators are consistent but biased in small samples (Stock, 1987); 2) the error correction model can be used to precisely estimate the cointegrated time series. The econometric interpretation of EMH is usually carried out within an error correction model and cointegration methodology (Fujihara & Mougoue, 1997).

The first to exploit the cointegration theory were Engle and Granger (1987), who made the revolutionary breakthrough in the efficiency testing

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[1] These studies used the data on heating oil, West Texas Intermediate and unleaded gasoline generally from 1984-1993. All of them found futures prices to contain unit root and require first differencing to become stationary.

[2] They made estimations for heating oil, gasoline and West Texas Intermediate Crude oil.

instruments. Following them, Johansen and Juselius (1990) came up with statistical methods to test for cointegration using the maximum likelihood estimation.

Most researchers use the cointegration models to deal with efficiency to ensure the robustness of the results. Their findings were controversial, some found specific markets to be efficient, others not. Using Johansen approach Fortenbery and Zapata (1993) tested the efficiency of corn and soybean markets of North Carolina. They found the markets to be efficient. Lai and Lai (1991) checked the Johansen's method on testing for efficiency of the foreign exchange market in the USA. Mckenzie and Holt (1998) performed several tests for efficiency of the U.S. futures markets for cattle, hogs, corn, soybean meal and broilers. They found all markets except broilers to be efficient. Garcia (1988) found evidence for semi-strong efficiency for live cattle, Back (1994) tested for efficiency for the range of markets covering cattle and corn, claiming that they are sometimes efficient depending on the time horizon chosen. Ma (1989) also found the evidence of efficiency for the oil futures, however, she argued that composite forecasting models provide better predictive power than futures prices (Kellard et al., 1999).

When choosing the futures lag as a horizon period, one should be especially careful to avoid time overlapping problem. That happens when the holding periods do overlap, for example, when the horizon is sampled from the specific day larger than a month for monthly delivery futures contracts. Such informational overlapping causes the autocorrelation problem in time series (Hansen and Hodrick, 1980), meaning that the previous future contract will be still traded on the exchange, while the price for the next contract is sampled. The futures prices for monthly contracts are therefore selected to be 28 days backward from the last day of contract life. For two- or more month contracts, it is better to use the 56-day horizon. To be more precise in their estimation of the efficiency hypothesis some researchers consider also the seasonality factor. The important question arises from the presence of seasonality in the time series. The point is that strong seasonality patterns in time series may be responsible for not incorporating all the information into prices, therefore creating inefficiency. Hylleberg (1992) described seasonality as systematic movement of prices within the year due to some changes in weather, calendar or timing decisions of agents. Such decisions are affected by the agents' expectations and preferences as well as available technology. Franses (1996) mentioned also that seasonality is mostly due to the weather conditions, but sometimes seasonal disturbances are driven by the agents behavior. When seasonal effects get strong we should include dummies to encompass the seasonality and make the unbiased informative test for efficiency.

To sum up, the conventional steps of informative test for futures market efficiency are the following: first, you test the time series for cointegration and then, secondly, verify whether future price when buying a contract is the good predictor for the spot prices at exercise date (Lai and Lai, 1991). As said above, the models for cointegration could be well represented by the error-correction framework described in Granger (1986).

Now we come to the specific models presented in literature. These models try to estimate efficiency taking to consideration major problems, namely, serial correlation of errors, endogeneity, simultaneity, cointegration of regressors. There is not any model covering all the drawbacks, each model is successful as a remedy for particular problem but not all at once.

Moosa and Al-Loughani (1994) tested for the efficiency of the futures market for West Texas Intermediate. The paper found significant correlation in equation's errors. Moosa used West's (1988) adjustment of the standard errors. This adjustment helps to avoid serial correlation in equation's errors and to obtain asymptotically normal test results even if regressors are integrated. However, they still had biased results. West adjustment procedure required the nonstationary regressors with nonzero drift component that was not present in any of time series analyzed by Moosa et al.

Phillips et al. (1991) applied nonlinear estimation procedure with remedy for both serial correlation in the errors and endogeneity of regressors (the same as simultaneity problem). Nonlinear least squares estimation produced test statistics with standard asymptotic distributions, which made it possible for testing the parameter restrictions a=0 and b=1. The specification model of nonlinear least square estimation looked as following (Phillips et al., 1991):

$$S_t = \alpha + \beta F_{t-1} + \sum_{i=1}^{n} \eta_i (S_{t-i} - \alpha - \beta F_{t-i-1)} + \sum_{j=-L}^{L} \phi_j \Delta F_{t-j} + u_t \qquad (5)$$

Phillips used Ljung-Box (1978) Q-statistics to test for the autocorrelation of the equations errors.

An alternative way to estimate the efficiency is to imply some transformations to the model until it has a form with only stationary variables. Here the "basis regression" comes (McNown, 1996) :

$$S_t - S_{t-1} = \alpha + \beta (F_{t-1} - S_{t-1}) + \mu_t \qquad (6)$$

However, Liu and Mandella (1992) found the evidence of the simultaneity bias in this specification. The simultaneity bias comes from the fact that lagged variables enter the equation (6) as a regressor and dependent variable at the same time. Therefore this test is a non-informative one.

In previous models prices were used for explanatory variables of the models. Here is a different approach.

Fujihara and Mougou' (1997) employed a regression of excess futures return on their own lagged values:

$$\Delta F_{t-1} = \alpha + \sum_{t=2}^{n} \beta_i \Delta F_{t-i} + \varepsilon_t \qquad (7)$$

Fujihara found heating oil and gasoline futures markets to be inefficient. But the criteria of efficiency were not reasonable. He argued the market to be efficient when the return on future contract is unpredictable. The critique of the paper came from Dwyer (1992) that has proved predictability of returns to depend on the data generation process and has nothing to do with efficiency.

The methodology developed even further. For example, Hakkio and Rush

(1989) renormalized the cointegration equation to end up with the following specification:

$$S_t - S_{t-1} = \alpha + \beta_1(F_{t-1} - F_{t-2}) + \beta_2(F_{t-2} - S_{t-1}) + \sum_{i-1}^{n} \eta_i \Delta S_{t-i} +$$

$$+ \sum_{j=2}^{m} \delta_j \Delta F_{t-j} + \mu_t \qquad (8)$$

Efficiency requires both $\beta_1, \beta_2 = 1; \mu_i, \delta_j = 0, \forall i, j$. Hakkio's specification is endowed with the same endogeneity problem as the "basis model" in (6). Barnhart, McNown and Wallace used simulations to demonstrate the simultaneity problem in the model and reported (8) to be non-informative test.

All above described tests are hardly considered to be informative, because of their problems (simultaneity, correlation etc). The informative type of test uses the principle of data generation process (DGP) equivalence for spot and lagged futures prices. We can express the efficiency by following the data generating process (DGP) of the time series proposed by McNown et.al.(1996):

$$S_t = g(X) + e_t \qquad (9)$$

$$F_{t-1} = g(X) - v_{t-1} \qquad (10)$$

where g(X) is a function of lagged variables determining the spot and futures prices. If the DGP is equal for these two time series, then there exist a strong evidence of efficiency of the market. Almost two decades ago Engle and Grenger (1987) presented the model, where the DGP of time series are of the error correction form. This model looks like this (Engle et al.,1987):

$$S_t - S_{t-1} = \alpha + \delta(F_{t-2} - S_{t-1}) + \sum_{i=1}^{m} \eta_i \Delta S_{t-i} + \sum_{j=2}^{n} \phi_j \Delta F_{t-j} + \varepsilon_t \qquad (11)$$

The specification gives robust results, showing the predictive power of lagged futures prices. Engle set *m, n* to be equal to the maximum number of lags, which are significant based on *t*-statistics.

The paper of Wei Bai et al. (2000) is of particular importance for me, since it estimates the efficiency of two electricity futures contracts in the U.S. (Palo-Verde and COB). To encounter the issues of error's correlation, endogeneity of regressors and cointegration, paper used the model specification presented in (5). This is Phillips-Loteran procedure, described above. The data for analysis were provided by FIMAT USA, Inc., New York. There were included daily electricity futures prices series covering the period from April 1996 through March 1998. As a result, the paper found the evidence for market efficiency at the 5% significance level. The futures and spot prices series in this test supported the relationship characterized by the slope of one and zero intercept. The residuals from the cointegration relationship of spot and futures series were found not to have autocorrelation according to Ljung-Box Q statistics. Such results prove the electricity futures market in US to be efficient. One possible explanation could be the deregulation and major changes in the electricity industry in recent years.

Drawing a conclusion, I need to mention the key message the literature provides. Regardless of the technical arsenal used to evaluate the commodity futures market efficiency, not taking to the account endogeneity and nonstationarity features of spot and futures time series may bring to misleading results. Economists who used the data in nonstationary form had non-informative tests of efficiency, without any empirical value. Even those employing stationary transformations still did not account for endogeneity present in time series. However, there are some successful examples, like Crowder and Hamed (1993), who represented their informative model (11).

The statistical techniques evolutionary developed over time and now we have high-quality instruments to test the efficiency of the commodity markets.

The goal of my paper is to use an informative test to evaluate the efficiency of electricity futures markets in sample countries and calculate the relative degree of efficiency. The approach would be useful for planning futures electricity market in Ukraine.

Chapter 3

METHODOLOGY

Data description

To analyze the efficiency of the market we need two time series: spot prices series, that includes all the spot prices at maturity dates, and futures time series that incorporate future contract prices taken some days back from their maturity (so called forecast horizon). We have 2 years and 7 months of monthly contracts for Germany that is equal to 31 observations (2002-2004). The data is retrieved from the website of European Energy Exchange (EEX) in Leipzig. The data for France and Austria need to be pooled, because it is only few month available for these countries. Norway dataset provides me with the largest 10-year weekly observation data set (1995-2005), which constitute 472 observations. This dataset is retrieved from the official Scandinavian countries Energy exchange – NordPool – under the disclaimer to use the data only for research. The construction of such time series needs extra information. The simple matching mechanism requires matching each maturity spot price with corresponding futures prices sampled some days before. However, this future price needs to be sampled less than a month long from maturity spot. Otherwise, we have autocorrelation problems (Hansen et. al., 1980), in a sense that the previous contract will still be traded when the matching price for the new contract is sampled. For instance, consider the following scenario: you take more than 1-month forecasting period, say 40 days. Now, if maturity spot price for December contract is sampled on December 31, the matching futures prices is taken 40 days back, being sampled on November 21, when November contract is still traded. The periods overlap, so you suffer from overlapping problems described in Hansen et.al. (1980). To avoid such problems, we sample matching future price 28 days back (less than 1 month) from the corresponding maturity date for Germany and 4 days back for NordPool weekly contracts. However, such an approach requires complicated notation used in the model, I will address this issue later in the chapter. The descriptive statistics on the data is provided in Appendixes A, B.

Model specification

To expose the mathematical model let us first go through all the econometric issues of the quasi-error correction model used in the paper.

My work consists roughly of the following stages: first, check for nonstationarity in time series; then test for cointegration; and finally check for efficiency, which is the main goal of the paper.

The initial step of analysis encompasses the fact that for time series to produce some kind of cointegration relationship they should be nonstationary. Therefore, I have to figure out whether the time series for spot and futures prices are nonstationary, in other words, containing unit root. According to the theory, time series are stationary when they have mean and variance constant over time and the covariance depends only on the lag between two time periods. If the series does not satisfy the above condition, it is said to be nonstationary. To check for nonstationarity I employ the Augmented Dickey-Fuller (ADF) or Phillips-Perron tests (Chowdhury, 1991; McKenzie and Holt, 1998). The null hypothesis of the ADF test is that time series are nonstationary. If the obtained test absolute estimate is less than critical value, then it is a strong evidence not to reject the unit root hypothesis. I will perform the ADF test for both spot and future prices of electricity contracts covering all the periods available from sample countries. The important issue is not only the stationarity but also the order of integration. This order equals to the number of times the series should be differenced to become stationary. So, if I find the data nonstationary, I will replicate the ADF test for differences of the series.

When the stationarity and integration order issues are clear, I can start estimating the cointegration relationship between time series. From the theory, time series are cointegrated when there exist such a vector of coefficients that creates a linear combination of these I(n) series, which is stationary. Moreover, cointegration requires series to be of the same integration order.

So far, let's take the simple model:

$$s_t = \alpha + \beta f_{t-1} + u_t \tag{3.1.}$$

or

$$u_t = s_t - \alpha - \beta f_{t-1} \tag{3.1.1}$$

where s_t stands for the logarithm of spot price and f_{t-1} means the logarithm of futures contract price 28 days back from the maturity date (or 4 days for Norway), used as a predictor for s_t. If the s_t and f_{t-1} series are nonstationary and integrated of order I(1) and we find such a vector V' that:

$$u_t = V'Y_t \tag{3.2.}$$

where $Y_t = (s_t, f_{t-1}, 1)'$, $V' = (1, -\beta, -\alpha)$ and u_t is stationary, this fact means s_t and f_{t-1} are cointegrated, V' being the cointegration vector.

If series are of different order of integration or there does not exist a cointegration vector to form their linear combination, then such series are not cointegrated and may drift apart without sharing any common trend. In this case, we say futures prices are of no use to predict the future spot price.

I am going to use the Johansen's cointegration test. Consider a general k-th order VAR model:

$$\Delta Y_t = D + \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{3.3.}$$

where Y_t is vector of series tested for cointegration of [nx1] dimension; $\Delta Y_t = Y_t - Y_{t-1}$; D stands for deterministic term taking different forms in accordance with the data properties; Π, Γ are coefficient matrices; k is chosen by Schwarz Information Criteria, so that ε_t is a white noise (Johansen and Juselius, 1990).

The maximum number of cointegration equations (vectors) is equal to the rank of matrix Π. If rank of Π =0, there is no cointegration in time series. The maximum rank of matrix Π cannot be higher than the number of variables in the regression.

The two test statistics proposed by Johansen (1998) are trace and maximum eigenvalues tests:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \tag{3.4.}$$

$$\lambda_{\max} = -T \ln\left(1-\hat{\lambda}_{r+1}\right) \tag{3.5.}$$

$\hat{\lambda}_1 ... \hat{\lambda}_r$ are the r largest squared canonical correlations between the residuals from the regression of ΔY_t and Y_{t-1} on $\Delta Y_{t-1}, \Delta Y_{t-2} .... \Delta Y_{t-k-1}$ and 1 respectively. In my test for efficiency there are two variables, therefore, the rank could be "0", "1" or "2". In the first and last cases ("0" or "2") there is no cointegration, in the second ("1")– there is one cointegration equation.

After determining the cointegration relationship between spot and futures prices of electricity I am going to estimate the vector error correction model (VECR) obtained from 3.1. This model will include the differenced lags of each time series to capture the short-run deviation from long-run trend and correction component, which captures the divergence of series from short-run deviation to long-run trend. The VECR model is represented as follows:

$$\Delta s_t = \theta_0 + \theta_1 \left(f_{t-1} - s_{t-1}\right) + \sum_{i=1}^{k} \lambda_i \Delta s_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta f_{t-i} + \varepsilon_{t1}$$

$$\Delta f_t = \xi_0 + \xi_1 \left(f_{t-1} - s_{t-1}\right) + \sum_{j=1}^{k} \lambda_j \Delta s_{t-j} + \sum_{j=1}^{k} \gamma_j \Delta f_{t-j} + \varepsilon_{t2} \tag{3.6.}$$

I test for the cointegration equation: $f_{t-1} = s_{t-1}$. The VECR also includes *k* differenced lags. To estimate the efficiency through the predictive power of futures prices on spot prices, we use the first line, and we are left with the following short-run efficiency testing specification:

$$\Delta s_t = \theta_0 + \theta_1 (f_{t-1} - s_{t-1}) + \sum_{i=1}^{k} \lambda_i \Delta s_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta f_{t-i} + \varepsilon_t \qquad (3.6.1.)$$

However, unless there is exactly 28 days between maturity dates, f_{t-1} and s_{t-1} are not sampled at the same day. Hence, the periods ($s_t - s_{t-1}$) and ($f_{t-1} - f_{t-2}$) will overlap and the results of (3.6.) will be biased. For example consider: s_t is December 31, s_{t-1} is equal to November 30; however f_{t-1} is equal to December 3 (we use 28 days forecast horizon, see (3.1.1),

and f_{t-2} stands for November 3. To avoid overlapping problem we would better modify the initial model (3.1.): (Kellard et al., 2000)

$$s_t = \alpha + \beta f_{t-\tau} + u_t \qquad (3.6.2)$$

here we use s_t to represent the maturity date, $f_{t-\tau}$ stands for 28 days back from maturity date " t ". τ means 28 days. Now our data is organized this way: for each s_t there is a corresponding $f_{t-\tau}$. It is so sampled, that we have a time series of maturity dates and a time series of "28-days-back" dates. Next, we need to create two new time series: f_t and $s_{t-\tau}$. To incorporate all the changes into our model we use the following specification: (Kellard et al., 2000)

$$s_t - s_{t-\tau} = \theta_0 + \theta_1 (f_{t-\tau} - s_{t-\tau}) + \sum_{i=1}^{k} \lambda_i \left(s_{t-i} - s_{(t-\tau)-i} \right)$$

$$+ \sum_{i=1}^{k} \gamma_i \left(f_{t-i} - f_{(t-\tau)-i} \right) + \varepsilon_t \qquad (3.7)$$

where τ means 28 days back; " i " equals one month. With this model, number of lags k specifies how many months we want to count backwards.

Models (3.1.) and (3.7.) are considered the working specifications for testing long-run and short-run efficiency respectively.

We first consider model (3.1.). It explains the long-run relationship between futures prices 28 days back from the maturity of the contract and spot price at maturity day. For the market to be efficient, we need not only time series to be cointegrated, but also to fulfill the cointegration restrictions: $\beta = 1$ and $\alpha = 0$. Using the same notation as in (3.1.1.), we continue with cointegration analysis. Therefore, for spot and futures time series to be cointegrated, linear combination $u_t = s_t - \alpha - \beta f_{t-\tau}$ or equivalently from (3.2.) $u_t = V'Y_t$ should be stationary. The market efficiency hypothesis could be tested by imposing restrictions on the cointegration vector $V' = (1, -\beta, -\alpha)$. Our hypothesis claims $\beta = 1$ and $\alpha = 0$. Thus, we could easily express the restrictions on cointegration vector as $V' = (1, -1, 0)$. This vector enters the error-correction model and produces loglikelihood estimate. By comparing such restricted model with unrestricted (3.1.) we can derive the likelihood ratio test for our restriction. The test statistics follows χ^2 distribution with 2 degrees of freedom. The same methodology is applied to test the individual efficiency hypothesis of $\beta = 1$. Important observation: the individual efficiency hypothesis is a stronger indicator of efficiency than the joint restriction. That is because the intercept could happen non-zero because of risk-premium and/or transportation costs even when the market is efficient.

Next step after testing restrictions is to run model (3.7.) both with and without lagged differences. Employing this procedure, we could see if the coefficient θ_1 is sensitive to the model specification in respect to inclusion of lagged differences. θ_1 is an adjustment coefficient in the quasi-VECR model, which shows how gradually the deviation from the long-run trend is eliminated. Under sensitivity I mean the considerable change of the coefficient depending on whether we include the lags or not. Thus, if θ_1 happens to be very sensitive to inclusion of lagged differences, that means lags possess some valuable information. Therefore, the market as of model (3.1.) is inefficient. We can also apply the hypothesis test for all lags coefficients to be jointly zero. This test determines if the lags could be easily omitted. If they cannot, we conclude the market inefficiency.

Relative measure of efficiency

Now we come to the estimation of the relative measure of efficiency. This measure has a strong advantage. The idea is not to say that market is efficient or not, but to explain to what extend it is efficient. Moreover, relative measure will help explain which portion of inefficiency is due to poor predictive power and which portion is caused by other factors. Equation (3.7.) provides the comparative forecast of spot price. The error variance of that forecast ε_t could be obtained from the fitted regression (3.7.). However, the efficiency would also imply the forecast of $f_{t-\tau} + E[(s_t - f_{t-\tau})]$, allowing for premium or discount in future prices. The error variance of this predictor could be estimated through the sample variance of $(s_t - f_{t-\tau})$. The ratio of these two error variances then provides the measure of the efficiency of future prices as predictors for spot prices. Therefore, the short-run efficiency measure has the following form: (Kellard et al., 2000)

$$\phi_c = \frac{(n-2k-2)^{-1}\sum_{t=1}^{n}\hat{\varepsilon}_t^2}{(n-1)^{-1}\sum_{t=1}^{n}\left[(s_t - f_{t-\tau}) - \overline{(s_t - f_{t-\tau})}\right]^2} \tag{3.8.}$$

where n stands for the number of observations in equation (3.7.), (2k+2) is the number of estimated parameters in model (3.7.). The numerator is the error variance from the model (3.7.), while denominator is the sample variance of the forecast error. In case ϕ_c =0, the futures market is absolutely inefficient, in case of ϕ_c =1, the market is efficient. The values of ϕ_c in range between 0 and 1 means the market to be relative inefficient.

From the model (3.7.) it becomes obvious that the inefficiency may stem from the fact that coefficient θ_1 is different from unity or lagged variables contain some explanatory value. There is an empirical way to measure the deviation of θ_1 from unity. Kellard et al., (2000) found high positive (0.96) correlation between the deviation of θ_1 from unity and inefficiency of the futures contracts in his data. Thus, it is clear that the main reason of the inefficiency is a result of base coefficient deviation from unity. (base coefficient is θ_1). Hence, the inclusion of lagged variables explains only a small degree of inefficiency.

The relative coefficient of efficiency ϕ_c is statistically significant measure of the efficiency, not necessarily economically significant one. This happens due to the concept of the significance level, chosen for estimation. Ceteris paribus, we can say that failing to reject the hypothesis does not necessarily mean the strong evidence to support this hypothesis. The chance to fail to reject the hypothesis is higher with small sample size and lower level of significance. If we have a large sample, even small degree of inefficiency will cause the rejection of the hypothesis. Real world and statistical significance measures do not coincide.

To be able to see which forces cause inefficiency we need a modified measure to estimate the efficiency. I will use the measure of efficiency developed by Kellard et al. (2000):

$$\overline{R}_1^2 = 1 - \frac{(n-2k-2)^{-1}\sum_{t=1}^{n}\hat{\varepsilon}_t^2}{(n-1)^{-1}\sum_{t=1}^{n}\left[(s_t - s_{t-\tau}) - \overline{(s_t - s_{t-\tau})}\right]^2} \tag{3.9.}$$

and

$$\overline{R}_2^2 = 1 - \frac{(n-1)^{-1}\sum_{t=1}^{n}\left[(s_t - f_{t-\tau}) - \overline{(s_t - f_{t-\tau})}\right]^2}{(n-1)^{-1}\sum_{t=1}^{n}\left[(s_t - s_{t-\tau}) - \overline{(s_t - s_{t-\tau})}\right]^2} \tag{3.10.}$$

these two are related through:

$$\phi_c = \frac{1-\overline{R}_1^2}{1-\overline{R}_2^2} \tag{3.11.}$$

Such a measure shows which portion of the efficiency is explained by the predictive power of the futures prices and which is by lag inclusion. We normally expect high efficiency measure to be the cause of the excellent futures prices explanatory power. This measure however may yield different results sensitive to the horizon level chosen for the futures contracts.

Chapter 4

EMPIRICAL PART AND RESULTS

Testing for Market Efficiency

As was mentioned in the previous chapter, testing for efficiency requires several steps. I start with testing the variables for nonstationarity using ADF test. The results are given in the Table 1.

Table 1

Test for non-stationarity (ADF)

Variable	Test statistics	1% Critical	5% Critical	10% Critical	Comment
s_t-base (5 lags)	-1.573	-3.750	-3.000	-2.630	non-stationary *
f_{t-28}-base (5 lag)	-2.362	-3.750	-3.000	-2.630	non-stationary *
s_t-peak (5 lags)	-1.458	-3.750	-3.000	-2.630	non-stationary *
f_{t-28}-peak (1 lag)	-2.189	-3.723	-2.989	-2.625	non-stationary *
s_t-NordPool (8 lags)	-2.552	-3.443	-2.872	-2.570	non-stationary *
f_{t-4}- NordPool (3 lags)	-2.363	-3.443	-2.871	-2.570	non-stationary *

*- for 1,5,10% -critical level

I cannot reject the null about unit-root for any of the time series. However, the results are sensitive to the number of lags chosen. I used "durbina" command to check for the number of lags that ensure no autocorrelation (Durbin-Watson alternative h-test). Now I check for the order of integration in variables. The results given in Table 2 show that all time series are integrated of the same order - I(1). After I found all time-series to be integrated of the same order, I can start testing for cointegration between time-series using Johansen cointegration test. This procedure checks for the maximum cointegration rank. There are 2 variables in the model specification 3.1. Therefore, the maximum rank could be equal 2. The results of the cointegration procedure are in the Table 3.

Table 2

Test for the order of integration

Variable	Test statistics	1% Critical	5% Critical	10% Critical	Comment
D(s_t)-base	-6.470	-3.723	-2.989	-2.625	stationary*, I(1)
D(f_{t-28})-base	-7.545	-3.723	-2.989	-2.625	stationary*, I(1)
D(s_t)-peak	-5.768	-3.723	-2.989	-2.625	stationary*, I(1)
D(f_{t-28})-peak	-6.371	-3.723	-2.989	-2.625	stationary*, I(1)
D(s_t)-NordPool	-25.029	-3.442	-2.871	-2.570	stationary*, I(1)
D(f_{t-4})- NordPool	-21.731	-3.442	-2.871	-2.570	stationary*, I(1)

* 1%,5%,10% critical levels, ADF

Johansen cointegration procedure specifies the VECM (vector error correction model) of the 2-variable VAR described in 3.3. The rank of Π identifies the rank of cointegration. The results also include the maximum eigenvalues test statistics and trace-method statistics.

Table 3

Johansen cointegration procedure

Variable	H_0:r	eigenvalues	Trace statistics	5%- critical value	Comment
s_t-base, f_{t-28}-base	0	-	18.3737	15.41	Rank=1 Reject non-cointegration
	1	0.37894	3.0366	3.76	
	2	0.16463			
s_t-peak, f_{t-28}-peak	0	-	17.1004	15.41	Rank=1 Reject non-cointegration
	1	0.32917	3.5223	3.76	
	2	0.17339			
s_t-NordPool, f_{t-4}-NordPool	0	-	108.4207	15.41	Rank=1 Reject non-cointegration
	1	0.19560	3.3366	3.76	
	2	0.01342			

It is clear from Table 3 that for all the products the rank of cointegration is equal to 1, thus, spot and futures prices for each electricity product are cointegrated. I used 3 lags in all the specifications based on the Schwarz Information Criterion. I employed 5%-critical level benchmark.

Table 3.1

Cointegration vectors

Beta	Coef.	Std.err.	Z	$P>\lvert z\rvert$	[95% Conf. Inter.]	
ce_1						
s_t_base	1	-	-	-	-	-
f_{t-28}-base	-1.025572	.214074	-4.79	0.000	-1.445149	-.6059944
_cons	.0869615	-	-	-	-	-
ce_2						
s_t-peak	1	-	-	-	-	-
f_{t-28}–peak	-.3448255	.2717534	-1.27	0.204	-.8774523	.1878013
_cons	-2.339018					
ce_3						
s_t -NordPool	1	-	-	-	-	-
f_{t-4}-NordPool	-.9873825	.0208104	-47.45	0.000	-1.02817	-.9465949
_cons	-.0527766					

Next, I test for unbiasedness of the long-term specification 3.1. using LR test. The joint hypothesis implies $\alpha = 0$ and $\beta = 1$ imposed on cointegration regression 3.1. Test statistics follows the χ^2 distribution with 2 degrees of freedom. The hypothesis is being tested through the likelihood ratio test. The results are given in Table 4.

Table 4

Test: $\alpha = 0$ and $\beta = 1$ in cointegration regression 3.1

Product	χ^2 (2)	p-value
Germany-base (monthly)	0.18356	0.90<p<0.95
Germany-peak (monthly)	0.89512	0.50<p<0.75
NordPool (weekly)	0.2448	p=0.9

As we can see from Table 4, I cannot reject null hypothesis about market efficiency for all the products. However, this means all the markets are efficient in long-term. Of course, long-run efficiency is necessary but not sufficient condition for short-run efficiency, which I examine further.

In Table 5 one can find the results of running OLS on the short-run efficiency specification 3.7. The number of lags used is 3. This number is obtained from step-by-step regressing with initially setting lag number equal 10 and then dropping the 10%- insignificant lags.

Table 5

OLS regression for

$$s_t - s_{t-\tau} = \theta_0 + \theta_1 (f_{t-\tau} - s_{t-\tau}) + \sum_{i=1}^{k} \lambda_i (s_{t-i} - s_{(t-\tau)-i}) + \sum_{i=1}^{k} \gamma_i (f_{t-i} - f_{(t-\tau)-i}) + \varepsilon_t$$

	Germany-base	Germany-peak	NordPool
θ_0	-.0716071 (-1.47)	.0377363 (0.78)	-.0151254 (-3.10)
θ_1	.945363 (8.25)	.4567461 (2.41)	-.826183 (-23.35)
λ_1	.2474308 (2.04)	.4069823 (2.42)	-.250627 (-7.06)
λ_2	.265573 (2.30)	.2828137 (2.23)	-.1298646 (-3.67)
λ_3	.1406546 (1.33)	.1514352 (1.97)	-.0659286 (-1.85)
γ_1	-.4768455 (-2.50)	.2562512 (1.52)	.3341169 (4.74)
γ_2	-1.146352 (-2.61)	.3233666 (1.74)	.2860282 (4.11)
γ_3	-.2137368 (-0.32)	.2279625 (1.51)	.0685682 (0.98)
	R-squared = 0.8114 Adj R-squared = 0.7454 Root MSE = .15792	R-squared = 0.8602 Adj R-squared = 0.8177 Root MSE = .14607	R-squared= 0.5593 Adj R-squared = 0.5526 Root MSE = .10256

Note:t statistics in parantheses

For comparison, I present Table 6 with regression 3.7 without lags. As was predicted by the theory, coefficient of the basis θ_1 is very sensitive to the inclusion or exclusion of differenced lags for all products except NordPool. Such a result means that lags contain some useful information, therefore short-run specification for Germany base and peak electricity is not efficient. However, NordPool happens to be more efficient.

Table 6

OLS regression for

$s_t - s_{t-\tau} = \theta_0 + \theta_1 (f_{t-\tau} - s_{t-\tau})$

	Germany-base	Germany-peak	NordPool
θ_0	-.0172049 (-0.48)	-.0332917 (-0.79)	-.0145409 (-2.88)
θ_1	.8094632 (8.12)	.7570032 (7.55)	-.7878642 (-21.32)
	R-squared = 0.6946 Adj R-squared = 0.6841 Root MSE = .17349	R-squared = 0.6628 Adj R-squared = 0.6512 Root MSE = .20204	R-squared = 0.4922 Adj R-squared = 0.4911 Root MSE = .10949

Note:t statistics in parantheses

To obtain the full picture of what is going on here, I test for the restriction of all lags being jointly zero. The results are in Table 7. Note however, that there is a small number of observations used in the test.

Table 7

Join Test of Zero Restrictions on the Coefficients of the Lagged Variables

Product	F	p-value
Germany-base	F(6, 20) = 2.31	Prob > F = 0.0742**
Germany-peak	F(6, 23) = 5.41	Prob > F= 0.0013*
NordPool	F(6, 460) = 11.67	Prob > F = 0.0000*

* 5% critical value, ** 10% critical value

Not surprisingly Germany peak and NordPool contracts rejected the null about zero lags at 5% critical level, when Germany base rejected efficiency at 10% level. Overall, all the markets happened to be somewhat inefficient.

Measuring relative degree of inefficiency

Previous material is useful in estimating the efficiency of electricity futures market, however, it does not provide any measure of efficiency. To correct for this I employ the relative-degree measure of efficiency represented in Methodology Chapter of the thesis. Using measures 3.8.-3.11. I end up with degree of efficiency and inefficiency for the analyzed markets. See Table 8 for results.

Table 8

Relative Measure of Efficiency Estimation

Commodity	Germany-base	Germany-peak	NordPool
ϕ_c	0.694224	0.449659	0.816311
Degree of Inefficiency	0.305776	0.550341	0.183689
Deviation of θ_1 from unity	0.47	2.87	4.91
$\bar{R}_1^2$	0.761296	0.817662	0.55634
$\bar{R}_2^2$	0.656157	0.594497	0.456506

Table 8 provides interesting insight for the efficiency analysis. The NordPool is the most efficient by 81.6%, however, only 45.6% of that is explained by the futures predictive power, all the rest is due to other reasons not analyzed in the scope of this research (ex. liquidity, volume etc.). However, from the previous chapters we know that primarily two things can cause inefficiency: deviation of the basis coefficient θ_1 from unity (weak predictive power of the futures) and importance of the information conserved in lags. We can clearly see, that deviation from unity for NordPool electricity is the highest of all three types of contracts. Therefore, the futures predictive power is so low and explains only 45.6% of the efficiency measure. On the other hand, Table 6 and Table 5 show that sensitivity of θ_1 to the inclusion of lags is the lowest for NordPool, thus, the lags contain very little information, which usually is an evidence of efficiency. Overall, NordPool shows the highest efficiency measure, however, not because of the predictive power of futures. Possible explanations could be the shorter period of contracts (weekly instead of monthly) and low information value of lags. NordPool's efficiency might be also due to the high liquidity of the market, stemming from the fact that the whole Nordic region not just one country are trading their electricity contracts. The most of inefficiency in the NordPool is a result of high deviation of the basis parameter from unity.

Now I am trying to link the analysis to the actual deregulation path in both Germany and Nordic countries.

NordPool happens to be much more efficient than Germany base, not mentioning peak contracts. Why this is true? Let us see what contributed to high efficiency in Nordic electricity market.

The major effects from the electricity market deregulation in Nordic countries as of Bergman et al.(1999) are:

- The savings on costs have been limited, which is crucial for the countries with large hydro energy potential, where most costs are sunk. There has been a reduction in operation costs with competition in force.
- The investment potential is renewed, driven by the interest to replace the old producing capacities.
- Mixed effects on prices. Large consumers negotiated reductions in prices with new competitive market. The development of competitive environment in large and medium sized energy companies is slow. However, in general prices dropped in real

terms and became more flexible, reflecting the demand and supply conditions.

There are some possible reasons for NordPool to be much more efficient than Germany. One is a shorter maturity length, a week for NordPool instead of a month for Germany futures. Secondly, NordPool's high trading volume (545Tw in 2003), lower transaction costs (see Bergman et al. (1999)), variety of derivatives traded, higher liquidity could be additional explanation of the efficiency. NordPool's wide range of trading instruments includes futures, forwards, contracts for differences (CfD), day contracts etc. Probably there is also some difference in exchanges' regulatory structure and legislation.

As mentioned by Bergman et al. (1999), the results of deregulation in Germany are different from that of NordPool.

The electricity supply system in Germany is guided through the Energy Act: completely free entry at all stages, eligibility of all consumers. Representatives of the industry have reached an agreement, which set up the basic structure for access charges. Whether liberalization of the German electricity market works remains a paradox. There are movements in both directions. Distributors and large consumers are negotiating their terms of trade and switching supplier. Price for large end-user decreased by 8% so far. On the other hand, there are cases of strong evidence for the price collusion and anticompetitive behavior (see Bergman et all. (1999)). Therefore, efficiency picture for Germany is different from NordPool's. From Table 8 we see that base electricity contracts are efficient by 69.4% while peak are only 44.9% efficient, with corresponding futures predictive power of 65.6% for base and 59.4% for peak contracts. The lower futures predictive power for peak could be easily explained by the higher deviation of basis coefficient from unity and very high sensitivity for the lags inclusion, meaning lags contain valuable information and in addition to deviation of θ_1 cause inefficiency.

Drawing concluding remarks for all analyzed countries, I could obviously mention the leading role of deregulation in electricity market restructuring tendencies. Both Nordic countries and Germany achieved large price reduction and efficiency improvement with deregulation of the electricity market. The major force of the change was the European Electricity Derivative (1997) that declared the course of market deregulation.

By now NordPool system could be a good example for Ukrainian born electricity futures market. However, Germany provides valuable experience too. For example, to avoid speculation the base contracts should be introduces first, because they happen to be more efficient than peak ones. Indisputably, the shorter period contracts are preferred to longer maturities.

Economic cost of inefficiency

If NordPool is said to be 18% inefficient, what does it effectively mean for the market players? The proportional cost of hedging corresponds to the forecast error variance in this paper. The cost of hedging for electricity is represented by (Kellard et al. (1999)):

$$(S_t - F_{t-\tau}) / F_{t-\tau} \approx s_t - f_{t-\tau} \qquad (4.1.)$$

In view of hedger, it means that the variance of hedging cost would be 18% less if the market were efficient. The economic cost of inefficiency could be analyzed from the speculator point of view. The degree of inefficiency is of little value for the speculator if he can not use it to outperform the market in a sense of systematically earning risk-adjusted profits. To see if one is able to make profits by utilizing information about inefficiency we need to forecast the futures prices with an ARIMA model. The obtained forecasts are compared to actual prices. After that decision to buy or sell is made. As in Leuthold et al. (1989) the strategy is defined as follows: buy an electricity futures if the forecasted prices exceeds actual by some predefined value, and sell the futures if the forecast is lower than the actual. Replicating such strategy we end up with average return earned on the strategy. As Kellard et al. (1999) emphasize in their research they doubt the ability of speculators to wisely use the strategy, which however earns the abnormal profit being particularly high in periods of low price fluctuation. Such analysis is beyond the scope of my research. Anyway, we see that past empirical research proved the ability to systematically use inefficiency to earn profits. However, Kellard et al.(1999) noted that simulations with ARIMA model does not anticipate sudden shifts of the spot price. Garcia (1988) obtained similar results for live cattle futures market.

Therefore, it is obvious that inefficiency possesses economic value and is used by speculators to make profits; in addition, this value becomes more important in times of low prices variance.

Chapter 5

CONCLUSIONS

This paper tests the efficiency of the electricity futures market in Central and Northern Europe. After the European Electricity Directive in February of 1997, national economies started slow but consistent reforms in their energy markets. Deregulation opened the industry to all the participants, loosened the regulation basis, decreased the monopoly prices, broke entry barriers for new companies and forced competition and negotiation process. Future markets serve as indicators of the deregulation efficiency, because the efficient markets do not leave place for speculation, thus, no social costs for hedgers and final consumers of electricity. On the other hand, an inefficient market produces large opportunities for the speculators to consistently earn profits and charge higher prices, which pass through the inelastic demand on the consumer's purchasing power. The research is used for further implications for Ukrainian electricity futures market, which is around the corner. The paper examines the relative degree of efficiency for the European countries to develop some benchmarks as to what model to follow, how to price the contracts, which maturities are optimal etc. Even taking into account the fact, that Ukraine is not an EU member, it still makes the research of neighboring electricity systems valuable. The findings of the research are intuitive. Nordic countries' electricity market is most likely highly efficient due to integration of national electricity systems, shorter maturity contracts (for ex. day contracts), high liquidity and wide range of hedging instruments.

However, of total 81% degree of efficiency, futures as unbiased predictors for spot prices explain only 45%. Germany shows weaker efficiency of 69.4% and 44.9% accordingly for base and peak monthly contracts. The deregulation trend in Germany is kind of paradox - decreasing prices and access charges on the one hand, while strong evidence for increasing monopolistic behavior on the other.

Ukraine can use the findings of the paper to apply to its own futures market. The further research of the subject may also add the tests for non-European countries such as USA, Australia, Canada and others. In addition, this paper does not include analysis of such reasons for inefficiency as risk premiums, storage and transportation cost, seasonal demand and so on.

The policy implications for Ukraine result from the analysis made in this paper about factors contributing to high efficiency of the market. One of the clear observations is that base contracts happen to be more efficient and need to be introduced first, when the market is still weak. Later on, when market becomes stronger, peak contracts could be involved in trading. Ukraine definitely needs to start the futures market of maturities shorter than a month. A week is probably the best maturity period. The best model to follow is that of NordPool. Such model makes it possible to combine the electricity market of one country with neighboring markets, where Ukraine trades its electricity with (Russia, EU). The issues of instruments diversity and liquidity are of vital importance for successful efficient futures market. Ukraine needs a separate power exchange as a base for futures market. To start with futures we need also to study the European deregulation process in depth, analyzing its pros and cons. This will help to identify the optimal parameters for the electricity futures in Ukraine.

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APPENDIX A
Germany data descriptive statistics

Table1: Descriptive statistics for base spot and base futures prices variables:

```
                        S_base
-------------------------------------------------------------
      Percentiles      Smallest
 1%        17.63         17.63
 5%        19.52         19.52
10%        20.19         19.53       Obs                 31
25%        22.66         20.19       Sum of Wgt.         31

50%        26.76                     Mean          26.34839
                        Largest      Std. Dev.     4.676462
75%        29.18         31.29
90%        31.29            34       Variance       21.8693
95%        34.51         34.51       Skewness      .0975015
99%         35.9          35.9       Kurtosis      2.284743
```

```
                        F_base
-------------------------------------------------------------
      Percentiles      Smallest
 1%        17.63         17.63
 5%        19.52         19.52
10%        20.19         19.53       Obs                 31
25%        22.66         20.19       Sum of Wgt.         31

50%        26.76                     Mean          26.34548
                        Largest      Std. Dev.      4.67631
75%        29.18         31.29
90%        31.29            34       Variance      21.86787
95%        34.51         34.51       Skewness      .0993993
99%         35.9          35.9       Kurtosis       2.28529
```

Table2: Summary statistics for base spot and base futures prices variables:

```
   stats |    S_base    F_base
---------+--------------------
    mean |  26.34839  26.34548
     sum |     816.8    816.71
     max |      35.9      35.9
     min |     17.63     17.63
   range |     18.27     18.27
variance |   21.8693  21.86787
      cv |  .1774857  .1774995
skewness |  .0975015  .0993993
kurtosis |  2.284743   2.28529
     p50 |     26.76     26.76
```

APPENDIX A (CONTINUED)

Table 3: Descriptive statistics for peak spot and peak futures prices variables:

```
                  S_peak
-------------------------------------------------------------
      Percentiles      Smallest
 1%        24.1          24.1
 5%       25.34         25.34
10%       28.46         25.41       Obs                 31
25%       31.09         28.46       Sum of Wgt.         31

50%       37.47                      Mean          37.42935
                        Largest      Std. Dev.     7.935299
75%       41.19         48.57
90%       48.57         48.79       Variance       62.96897
95%       49.35         49.35       Skewness       .4387894
99%       57.93         57.93       Kurtosis       2.923373

                  F_peak
-------------------------------------------------------------
      Percentiles      Smallest
 1%       25.27         25.27
 5%       26.97         26.97
10%       30.64         29.15       Obs                 31
25%       34.26         30.64       Sum of Wgt.         31

50%       38.02                      Mean          38.90806
                        Largest      Std. Dev.     7.469302
75%       42.88         48.25
90%       48.25         52.83       Variance       55.79047
95%       54.25         54.25       Skewness       .5004793
99%          56            56       Kurtosis       2.990784
```

Table 4: Summarized statistics for peak spot and peak futures prices variables:

```
   stats |    S_peak    F_peak
---------+--------------------
    mean |  37.42935  38.90806
     sum |   1160.31   1206.15
     max |     57.93        56
     min |      24.1     25.27
   range |     33.83     30.73
variance |  62.96897  55.79047
      cv |  .2120074  .1919731
skewness |  .4387894  .5004793
kurtosis |  2.923373  2.990784
     p50 |     37.47     38.02
```

APPENDIX B

NordPool's data statistics

```
prices
stats     |    futures    spot
---------+--------------------
   mean |  180.6403   179.3771
    max  |    856.06      650.79
    min  |     46.26       43.612
skewness |  1.895304  1.056051
     p50  |     164.5       163.62
kurtosis |  12.63991    5.70785
   range  |     809.8      607.178
      sd    |  85.37519     79.50339
Obs.       471                 471
```