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Modelling Long-Term Electricity Contracts at EEX

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Modelling Long-Term Electricity Contracts at EEX

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Abstract:

The main aim of this paper is to develop and calibrate an econometric model for modelling prices of long term electricity futures contracts. The calibration of our model is performed on data from EEX AG allowing us to capture the specific features of German electricity market. The data sample contains several structural breaks which have to be taken into account for modelling. We model the data with an ARIMAX model which reveals high correlation between the price of electricity futures contracts (namely Phelix Base Fututes with next year´s delivery) and prices of long-term futures contracts of fuels (namely coal, natural gas and crude oil). Besides this, also a share price index of representative electricity companies traded on Xetra, spread between 10Y and 1Y German bonds and exchange rate between EUR and USD appeared to have significant explanatory power over these futures contracts on EEX.

Keywords: electricity futures, EEX, ARIMAX, emission allowances

JEL: C32,C53,G13,O13

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Introduction

The electricity market in Germany was liberalized during the late 1990s. The main aim of the liberalization process was to establish a sufficient level of competition among agents participating in the market. However, the electricity market structure remained oligopolistic[1] with high level of vertical integration. In year 2002 the Leipzig Power Exchange (LPX) and European Energy Exchange with the seat in Frankfurt am Main merged together and founded new energy exchange under the name European Energy Exchange (EEX AG) with seat in Leipzig. Nowadays EEX is the biggest market with energy in continental Europe with respect to both, turnover and number of agents. EEX enables trading in power, natural gas, coal as well as emission allowances. Besides the liquid daily spot market, electricity is also being traded in form of futures and option contracts.

The paper consists of six parts. The first chapter summarizes current theoretical and empirical literature concerning our topic. We focused mainly on papers which offer interesting methodology and which employ similar (or ideally the same) markets as in our case. Next chapter describes the specifics of the general model for futures pricing and its modifications that enable to use the model for our purposes. The third part is devoted to data analysis and methodology description. All variables are introduces and explained. The econometrical approaches we used are explained in the fourth part. The fifth chapter summarizes econometrical results obtained. At the end we provide a summary of the results, conclusive remarks and suggestions for future research.

Literature overview

This part contains the overview of recent theoretical and empirical literature discussing the topic of long-term electricity contracts modelling. The attention paid to this topic by researchers is not as large as it is in case of short-term modelling and the numbers of studies is limited. We would like to underline the three most important papers.

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[1] The four most important market players (namely E. ON, RWE, EnBW and Vattenfall Europe) represent approximately 85 % of the total net electricity generation capacity in Germany according to data provided by Bundesnetzagentur in 2007. Moreover, more than 60 % of this capacity is provided by two largest companies (E. ON and RWE).

The most influential paper from our point of view was written by Povh and Fleten (2009). In their paper authors focused on modelling long-term electricity forward prices with the data from the Nord Pool Power Exchange Market. Besides the empirical analysis they provide also a general approach for analyzing electricity markets. They modelled the relationship between prices of long-term forward contracts on fuels (such as oil, coal and natural gas), the price of emission allowances and imported electricity and the long-term price of electricity forwards.

The second important study written by Povh, Fleten and Golob (2009) is a valuable extension of the first paper. They modelled long-term electricity forwards with time to maturity between one and two years again at Nord Pool on weekly basis during the period of 2005 to 2007. Besides variables mentioned above they included also price of aluminium and in addition to this electricity price from neighbouring market (EEX) as explanatory variables. They used vector autoregressive model for long-term modelling and quite surprisingly found out that the gas prices were insignificant in this model.

The third interesting contribution was made by Redl (2007) who described a model for forecasting futures electricity price directly on the EEX. As a representative contract he chose year-ahead baseload forward contracts traded on this market. He found out that the forward prices are mostly influenced by futures prices of fuels (namely natural gas and coal) and CO_2 emission allowances. He also pointed out that if forward contracts are priced correctly, then both, futures and spot prices should follow the same trend corrected by risk premium (market value of risk affiliated with time). In his paper, he concludes that there is no persistent trend in the amount of the risk premium (which is fairly intuitive). What is more interesting is that according to Redl (2007) there is no persistent trend even in the sign of this risk premium.

Valuation of futures contracts

The standard approach used to calculate the price a futures contract is to meet so called no-arbitrage condition. This condition ensures that the futures contract is priced fairly and there is no possibility for risk-free arbitrage. Even thought this concept can be used for almost all commodities, it is not suitable for electricity futures since the electricity cannot be economically stored for an extended time period. Moreover, this model implies that there is no direct link between the spot and futures price. Thus the formula used for pricing a standard futures contract as it is described by equation (1) cannot be applied in our case:

$$F_{t,T} = S_{t,T} * (1 + r - \lambda)^{T-t} \qquad (1)$$

In equation (1) $F_{t.T}$ represents the price of futures contract, $S_{t,T}$ stands for the spot price of a given commodity, the term (1+ r – λ) denotes risk premium and T – t reflects time to maturity. The risk premium term in our regression analysis, namely the (1+ r – λ) powered to the remaining time to maturity deserves to be more discussed. This compensation for unexpected changes in the future spot price, consisting of risk free rate and the forward premium, can be affected in several ways. The first one we should have taken into account is the fact that this risk premium is positively correlated to the risk premium of particular fuels (e.g. gas and oil) since an increase in the fuels' risk premium is transferred also to risk premium of the electricity forward contracts. Moreover, it is obvious that the risk premium is also directly affected by the evolution of the reserve margin and this relationship is negative as this relation accounts for the scarcity of electricity. The particular risk premium components are discussed more in detail e.g. in the paper by Redl and Bunn (2010).

Because we want to find out the pricing formula for the case of electricity, we have to change this equation (1) in order to employ expected spot price $E(S_{t,T})$ instead of the spot one. This is done in equation (2) which provides the basic formula suitable for pricing electricity futures:

$$F_{t,T} = E(S_{t,T}) * (1 + r - \lambda)^{T-t} \qquad (2)$$

In order to obtain a linear model, we transformed equation (2) into a logarithmic form The final version of our equation is:

$$\log F_{t,T} = \log E(S_{t,T}) + (T - t) * \log(1 + r - \lambda) \qquad (3)$$

As Povh and Fleten (2009) argue that the term *log(1 + r – λ)* is relatively stable with far maturity[2] so the expected future spot price comprises most of the variability that explains futures price. Factors that determine future spot price are future supply and demand (unfortunately hardly predictable). Thus instead of them, variables directly influencing supply and demand are to be employed. The following variables can be considered to have significant impact on either demand or supply[3]:

1. fuel prices – gas, oil, coal
2. emission allowances
3. weather conditions
4. time factor

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[2] For the explanation of „far maturity" Diko, Lawford, Limpens (2006).

[3] Povh and Fleten (2009)

5. economic activity
6. other – historical or forecasted loads, electricity prices in neighbouring markets, market structure, regulation and future demographical development

Nevertheless, not all of these factors can be observed with sufficient frequency. Moreover, another limitation of their approach is an insufficient liquidity in some markets.

Data analysis and methodology

The electricity market in Germany is by far represented by EEX. As a reference time series we consider a yearly Phelix Base Futures with next year´s delivery. Our data sample contains data started from the beginning of 2006 till June 2009. Data in this period are observed on a daily basis which allows us for short-term modelling. Our dataset was trimmed from extreme observations and in addition to this, the EEX time series were transformed by linear interpolation.

As we mentioned above, we have to identify possible determinants of future spot price. Hereat we divide variables with possible explanatory power into several groups.

In the first group we include futures on fuel prices as they obviously influence the costs of electricity production. This group covers time series on oil, natural gas and coal. Oil prices are represented by a monthly futures contract of BRENT crude oil and a yearly futures contract of NYMEX WTI light sweet crude oil. Natural gas is represented by yearly futures of TTF gas from Zeebrugge hub. As coal is mostly OTC traded we consider TFS API4 price index (coal delivered in Amsterdam, Rotterdam and Antwerp harbour) in our model[4].

The second group of variables impacting the production costs of electricity are the emission allowances. The system of emission allowances within the European Union was firstly introduced in January 2005 and nowadays it is to be considered as an important factor influencing the price of electricity futures contract. Because of the long-term nature of our modelling, we incorporate one year-ahead futures contracts of emission allowances EU ETS[5].

The last group of variables are the ones reflecting financial market conditions and economic development – those variables might have indirect impact on electricity prices. The first of those variables is the EUR/USD exchange rate. Then we considered variables that measures

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[4] All the fuel prices data series are retrieved from Bloomberg and Reuters databases.

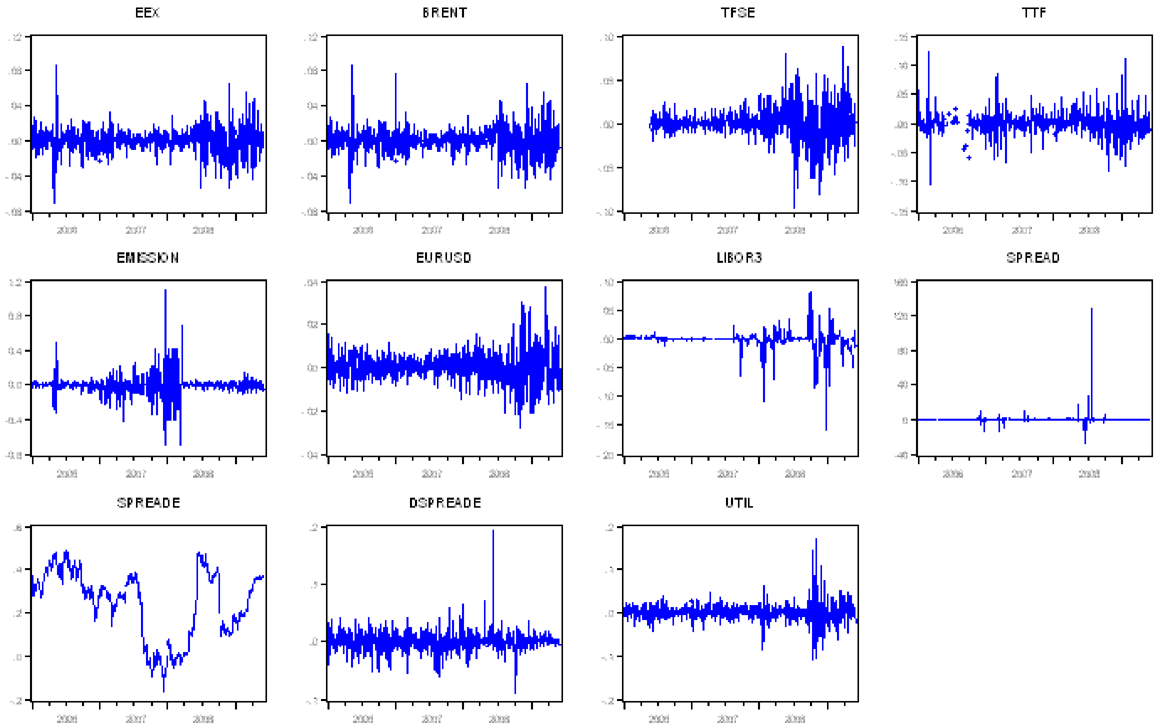
[5] The data on emission allowances were retrieved directly from EEX.

the risk premium associated with time factor of future contracts. This risk premium can be indirectly observed from a shape of yield curve. For this purpose we used variable SPREAD. This variable models the right part of the yield curve shape. SPREAD is defined as a difference between 10Y and 1Y government bonds in Germany This variable thus models the right part of the yield curve shape. The higher the value of the SPREAD variable the steeper the yield curve is, which means the higher risk premium for the later maturity is expected by the market.

The last explanatory variable is the Prime Utilities Index (UTIL) traded on Xetra. This index contains weighted results of share price evolution of following companies: E.ON AG, MVV Energie AG, RWE AG St and RWE AG Vz. This variable was included because we think that financial markets through this index variable are able to reveal the market expectations on the future price of electricity futures (these are then reflected in the share price). All of the time series mentioned in this paragraph were also retrieved from Bloomberg.

The evolution of all above mentioned variables (except for autoregressive coefficient AR) over specific time could be seen on the following graph:

Graph 1: The evolution of variables over time



Source: eViews

All graphs represent the evolution in the time series over time except for the first graph in the bottom panel which describes the evolution of SPREADE itself. These graphs at the first sight reveal high correlation between the evolution of electricity price of futures contracts at EEX and BRENT crude oil. Moreover, it is interesting to point out the dramatic change in SPREAD in the third quarter of 2008. This probably reflects the troubles in financial markets prior to collapse of Lehman Brothers. The shock to EUR/USD exchange rate was just temporary. We can observe that since September 2008 the variance of all variables employed in our model has substantially increased as a consequence of substantial financial turmoil. There is only one exception from this trend - the variance of price of emission allowances experienced substantial decrease starting from this date which can be explained by lower demand for emission allowances as a consequence of diminishing industrial production during the economic crises.

Econometric Analysis

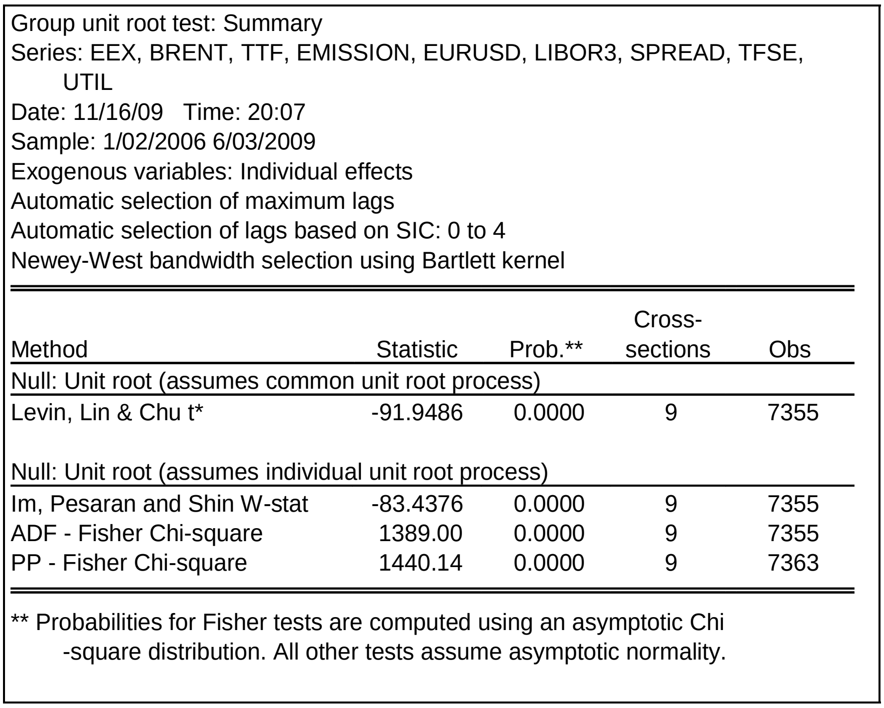
As all the variables are defined, we continue with description of the econometrical model for electricity futures. We apply ARIMAX – autoregressive integrated moving average model with exogenous input that is derived from simple ARIMA – autoregressive moving average model. The general form of the model we use is described by equation (5):

$$Y_t = \alpha + \sum_{i=1}^{p} \beta_i Y_{t-i} + \varepsilon_t + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \sum_{k=1}^{r} \gamma_k X_{t-k} \qquad (5)$$

where α is a drift, the first sum denotes an autoregressive term, ε_t is an error term, the second sum represents a moving average process of past error terms and the last sum are exogenous variables. All the data are going to be transformed into natural logarithms and then differenced in order to avoid spurious regression that could be caused by using possibly non-stationary series. The model we work with is estimated by using OLS method. The dependant variable is the price of long-term electricity futures contract.

For the purpose of econometric analysis we used the above mentioned data series. The observation period is 11/09/2006 to 5/4/2009.

Table 1: Unit root test

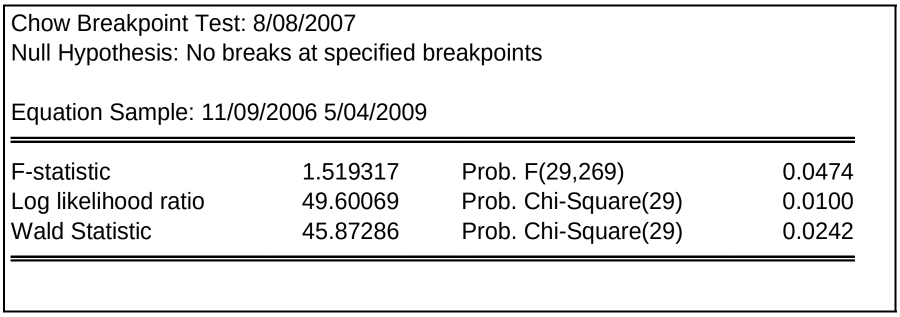


```
Group unit root test: Summary
Series: EEX, BRENT, TTF, EMISSION, EURUSD, LIBOR3, SPREAD, TFSE,
        UTIL
Date: 11/16/09   Time: 20:07
Sample: 1/02/2006 6/03/2009
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic selection of lags based on SIC: 0 to 4
Newey-West bandwidth selection using Bartlett kernel
================================================================================
                                                          Cross-
Method                              Statistic   Prob.**   sections     Obs
--------------------------------------------------------------------------------
Null: Unit root (assumes common unit root process)
--------------------------------------------------------------------------------
Levin, Lin & Chu t*                 -91.9486    0.0000       9        7355

Null: Unit root (assumes individual unit root process)
--------------------------------------------------------------------------------
Im, Pesaran and Shin W-stat         -83.4376    0.0000       9        7355
ADF - Fisher Chi-square              1389.00    0.0000       9        7355
PP - Fisher Chi-square               1440.14    0.0000       9        7363
================================================================================

** Probabilities for Fisher tests are computed using an asymptotic Chi
        -square distribution. All other tests assume asymptotic normality.
```

Source: eViews

At first we have to check whether the data series are stationary. To do so, we use unit root test[6]. The results are summarized in Table 1. It shows that both commonly used test (namely Augmented Dickey-Fuller test and Phillips-Perron test) reject the null hypothesis at very high levels of significance. Based on this finding we can treat the data series as being stationary.

Table 2: Structural breaks analysis - 8/08/2007



```
Chow Breakpoint Test: 8/08/2007
Null Hypothesis: No breaks at specified breakpoints

Equation Sample: 11/09/2006 5/04/2009
================================================================================

F-statistic               1.519317     Prob. F(29,269)              0.0474
Log likelihood ratio      49.60069     Prob. Chi-Square(29)         0.0100
Wald Statistic            45.87286     Prob. Chi-Square(29)         0.0242
================================================================================
```

Source: eViews

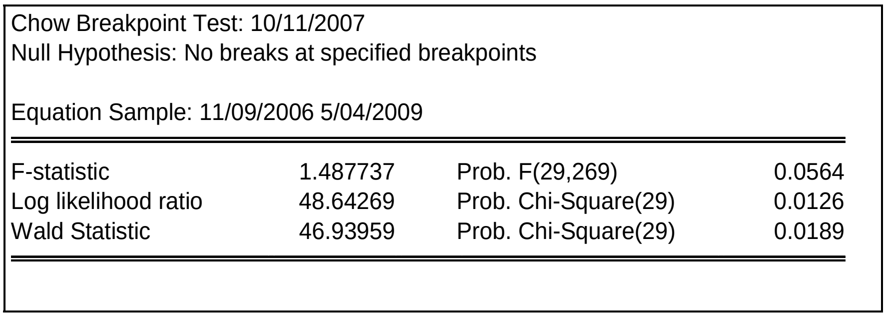
Application of standard OLS regression on the data sample revealed several problems. One of the most severe was the presence of structural breaks in the dataset. In order to identify them, we used Quandt-Andrews unknown breakpoint test and Chow Breakpoint test. These two

---

[6] Unit root test is a test (e.g. Augmented Dickey-Fuller (denoted as ADF in the Table 1) test or Phillips-Perron test (PP)) which is able to detect the possible non-stationarity within the time series.

tests indentified the presence of two structural breaks in our dataset with relatively high significance levels. This is shown in tables 2 and 3:

Table 3: Structural breaks analysis - 10/11/2007



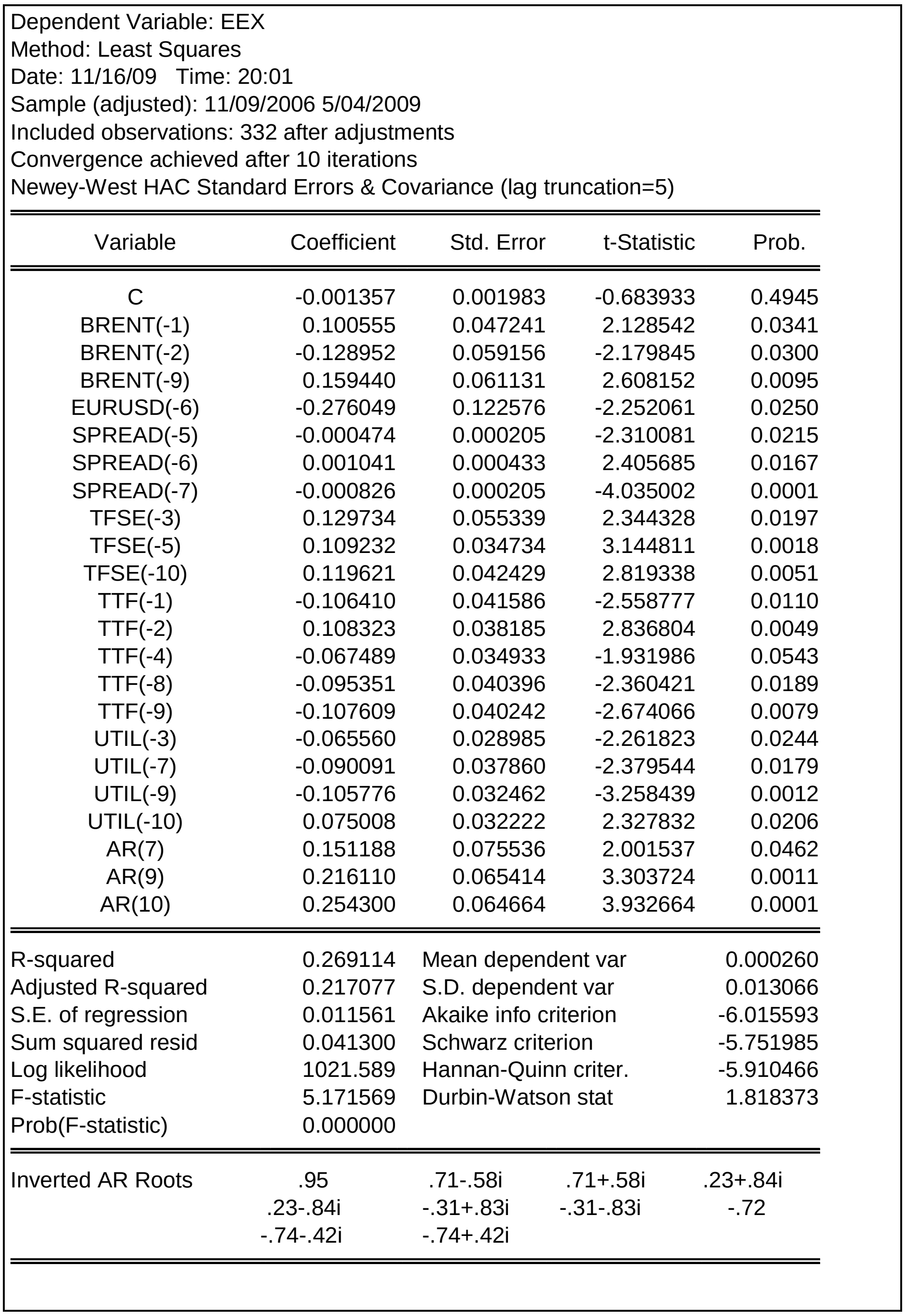
```
Chow Breakpoint Test: 10/11/2007
Null Hypothesis: No breaks at specified breakpoints

Equation Sample: 11/09/2006 5/04/2009
=====================================================================
F-statistic              1.487737     Prob. F(29,269)           0.0564
Log likelihood ratio     48.64269     Prob. Chi-Square(29)      0.0126
Wald Statistic           46.93959     Prob. Chi-Square(29)      0.0189
=====================================================================
```

Source: eViews

Another problem was related to heteroscedasticity of residuals. Moreover, it was not clear which form of heteroscedasticity the dataset exhibits. In order to solve these two issues (namely presence of structural breaks and heteroscedasticity of residuals) we decided to use Newey-West heteroscedasticity and autocorrelation consistent covariance estimates. These estimates provide more general covariance estimator than White estimate and it also returns results with high explanatory power even in the presence of both, heteroscedasticity and autocorrelation of unknown form. This enables us to use OLS method even when there are autocorrelated residuals and heteroscedasticity in the dataset. From now on, we will denote the estimator which was obtained by employing Newey-West estimator as the second approach. Moreover, all obtained results which follow are obtained by employing this second approach. The OLS method provided us with results described in Table 4.

Table 4 summarizes results of our model which was calibrated on 332 observations as they were collected during the period starting from 11/2006 until 5/2009. The adjusted R^2 of the model is higher than 0.20 which allows us to consider the model explanatory power as sufficient even in presence of higher volatility of almost all variables from the data sample after 09/2008 as a consequence of financial crises as mentioned in previous chapter.

Table 4: Econometrical results OLS

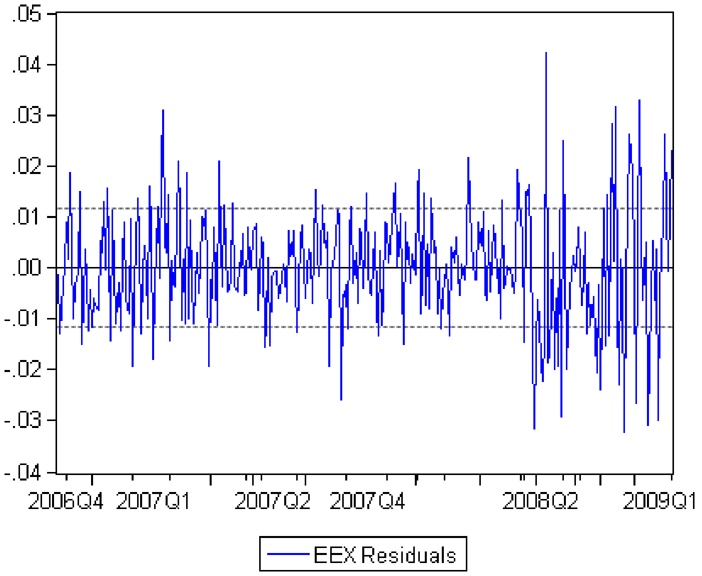


```
Dependent Variable: EEX
Method: Least Squares
Date: 11/16/09   Time: 20:01
Sample (adjusted): 11/09/2006 5/04/2009
Included observations: 332 after adjustments
Convergence achieved after 10 iterations
Newey-West HAC Standard Errors & Covariance (lag truncation=5)
======================================================================
        Variable        Coefficient    Std. Error    t-Statistic    Prob.
======================================================================

           C             -0.001357      0.001983      -0.683933     0.4945
       BRENT(-1)          0.100555      0.047241       2.128542     0.0341
       BRENT(-2)         -0.128952      0.059156      -2.179845     0.0300
       BRENT(-9)          0.159440      0.061131       2.608152     0.0095
      EURUSD(-6)         -0.276049      0.122576      -2.252061     0.0250
      SPREAD(-5)         -0.000474      0.000205      -2.310081     0.0215
      SPREAD(-6)          0.001041      0.000433       2.405685     0.0167
      SPREAD(-7)         -0.000826      0.000205      -4.035002     0.0001
       TFSE(-3)           0.129734      0.055339       2.344328     0.0197
       TFSE(-5)           0.109232      0.034734       3.144811     0.0018
       TFSE(-10)          0.119621      0.042429       2.819338     0.0051
        TTF(-1)          -0.106410      0.041586      -2.558777     0.0110
        TTF(-2)           0.108323      0.038185       2.836804     0.0049
        TTF(-4)          -0.067489      0.034933      -1.931986     0.0543
        TTF(-8)          -0.095351      0.040396      -2.360421     0.0189
        TTF(-9)          -0.107609      0.040242      -2.674066     0.0079
        UTIL(-3)         -0.065560      0.028985      -2.261823     0.0244
        UTIL(-7)         -0.090091      0.037860      -2.379544     0.0179
        UTIL(-9)         -0.105776      0.032462      -3.258439     0.0012
        UTIL(-10)         0.075008      0.032222       2.327832     0.0206
         AR(7)            0.151188      0.075536       2.001537     0.0462
         AR(9)            0.216110      0.065414       3.303724     0.0011
         AR(10)           0.254300      0.064664       3.932664     0.0001
======================================================================
R-squared                 0.269114    Mean dependent var        0.000260
Adjusted R-squared        0.217077    S.D. dependent var        0.013066
S.E. of regression        0.011561    Akaike info criterion    -6.015593
Sum squared resid         0.041300    Schwarz criterion        -5.751985
Log likelihood            1021.589    Hannan-Quinn criter.     -5.910466
F-statistic               5.171569    Durbin-Watson stat        1.818373
Prob(F-statistic)         0.000000
======================================================================
Inverted AR Roots           .95          .71-.58i      .71+.58i     .23+.84i
                          .23-.84i      -.31+.83i     -.31-.83i       -.72
                         -.74-.42i      -.74+.42i
======================================================================
```

Source: eViews

If we plot the residuals retrieved from the model with respect to time (as shown the Graph 2), we can see significant increase in the variance of residuals starting from second quarter of 2008. Even though, the results obtained points to relatively good performance of our model.

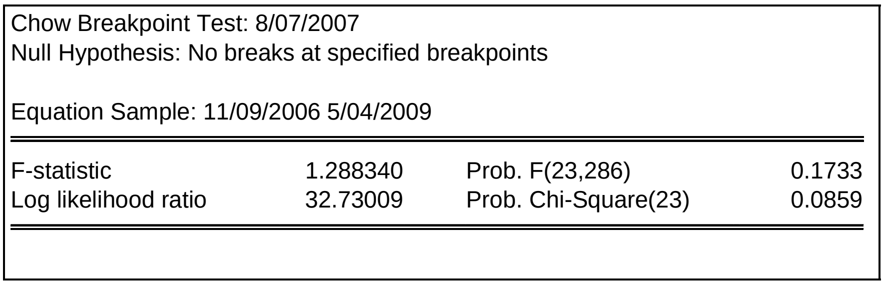
Graph 2: Plot of residuals with respect to time



Source: eViews

Although the obtained results of our model are satisfactory, we have to check whether there are still any structural breaks in the modified (second) approach or not. This was done by employing the Chow Breakpoint test. Output of this test is available in Table 5:

Table 5: Structural breaks analysis - 8/07/2007



```
Chow Breakpoint Test: 8/07/2007
Null Hypothesis: No breaks at specified breakpoints

Equation Sample: 11/09/2006 5/04/2009
=========================================================================
F-statistic              1.288340      Prob. F(23,286)             0.1733
Log likelihood ratio     32.73009      Prob. Chi-Square(23)        0.0859
=========================================================================
```

Source: eViews

The results in Table 5 shows that we cannot reject null hypothesis stating that there is no structural break on 8/7/2007 on 5% significance level. We can conclude that the modified dataset does not contain any structural break with high probability. This finding simplifies our further analysis.

Interpretation of results

This chapter contains economic interpretation of results obtained in the previous section. The stationarity of the data sample that was verified in the fourth part of our paper allows us interpret the obtained results. The Table 4 provides clear insights that, except for intercept and futures contracts on natural gas lagged by four periods (i.e. four months in our case), all variables are estimated as significant at least at 5 % level of significance.

More interesting, from the interpretation point of view are estimates of regression coefficients, or more precisely their signs. If we recall Table 4 presenting the results of regression analysis for the first model, we find out that most of the variables (namely BRENT, SPREAD, TTF and UTIL) the sign of the regression coefficient depends on the time lag. Thus our model detected that the relationship between dependent variable and certain explanatory variables is not stable. The way how is the dependent variable influenced by these explanatory variables is sometimes positive and sometimes negative. This is rather counterintuitive for the first sight. However, there can be effects driving the value of the lagged variable below zero. One of the variables with constantly positive sign of regression coefficient for all time lags was TFSE. The sign was in its case always positive. There is clearly a positive correlation between coal price and price of electricity futures contracts.

In order to evaluate whether the results are consistent even during the financial crises we took an exercise and tried to model two data samples before and after the crises. The results for both data sets were identical in terms of significance of particular variables, even though the size of residuals increased for the “crises” sample. Thus we can conclude that the model we used provides consistent results also during financial crises.

Conclusion

In this paper we examined the possible determinants of the price of futures electricity contracts at EEX. We did it by empirical analysis based on ARIMAX model. As a dependent variable we chose Phelix Base Futures with next year´s delivery. We tried to explain this variable be incorporating contracts on fuels (namely natural gas, oil and coal), emission allowances and indicators from financial markets (index based on assets performance, LIBOR and Germany 1Y and 10Y bonds, EUR/USD exchange rate).

The results are summarized in Table 4. This table demonstrates that all estimated variables have significant power in explaining electricity futures prices variability. The fact, whether a relationship between a certain variable and the electricity futures is positive or negative, depends on the time lag. The possible interpretation is that (especially in case of fuel contracts) it hinges on whether or not the “costs effects” dominates over “substitution effects". The exception to this is coal with persistent positive price effect for all time lags. The performance of the model measured as goodness of fit was relevant - our model is able to account for explain more than 25 percent of the variance observed in prices of electricity futures. In addition to this, even on these time series we can observe the impacts of recent financial crisis via substantial increase (with the exception of the price for emission allowances) in the variance in a corresponding period. This might lead to a decrease in the performance of our model.

If we would like to compare our results with other empirical literature considering the same topic, we can see that similarly to e.g. in Povh and Fleten (2009) and Redl (2007) we found out the significance of fuel costs or emission allowances.. Contrary to them, our analysis revealed that even natural gas has an explanatory power over electricity futures. Including other factor from the financial markets than the ones related to the evolution of interests rates seem to be rather innovative and thus it does not allow us to compare obtained results with previous empirical literature.

However, the comparison among particular papers is quite a hard issue since as we have already mentioned in the section dedicated to the literature overview, the number of studies whose aim is to study similar question as we have risen in our study. Moreover, two out of three papers mentioned in that part which was devoted to modelling a different market with electricity futures, namely the Nord Pool and therefore the results (and models used) need not to be fully comparable due to the different characteristics of these markets. However, in general terms we can point out that we can see that similarly to e.g. in Povh and Fleten (2009) and Redl (2007) we found out the significance of fuel costs or emission allowances. Contrary to them, our analysis revealed that even natural gas has an explanatory power over electricity futures.

The fact that we have included in our model the Prime Utilities Index traded on Xetra in order to account for the market sentiment seem to be rather innovative approach. Moreover, as the results of the model pointed out, this step caused an improvement in the explanatory power of it as all UTIL variables included in Table 4 were significant.

Although the fact that our model is relatively up to date it could be somehow treated as outdated due to rapid development of economic conditions caused by the ongoing financial crisis. Such crisis often changes the trends and relationships between particular variables. On the other hand, the "core" of revealed relationships we assume to stay unchanged. This creates suitable position for further research - to verify, whether even in the after-crisis period, the results we mentioned in our paper still hold. Moreover, also modelling the same data with different methods (e.g. cointegration or neural networks) might shed more light on this topic and provide interesting answers.

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