# THE ANALYSIS OF RELATIONS BETWEEN PRIMARY FUEL PRICES ON THE EUROPEAN MARKET IN THE PERIOD 2001-2011

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**Słowa kluczowe:** primary fuels market, Granger causality, VEC model

**Sumamry.** Safety and development of a country depends on its capability to provide the energy it needs. So far the majority of energy has been obtained from non-renewable sources, i.e. crude oil, natural gas and steam coal. The aim of the article is to present the relations between the prices of the most important primary fuels on the European market in the period between October 2001 and May 2011. Causality between the prices will also be investigated. The identification of the mechanisms influencing prices on the raw material market will be conducted using the method of multiple time series analysis. The results of the analysis reveal that in this period the prices of crude oil, natural gas and steam coal were in a long-run equilibrium. Market mechanisms make the prices increase together and decrease together in the long-run, which, one may be tempted to explain by fundamental factors (especially changing economic conjuncture) and weather (bitterly cold winter), both causing substantial changes in the demand for energy sources. However, it is contradicted by the analysis of Granger causality, which shows that the variables of the system should not be treated in the same way.

## 1. INTRODUCTION

Safety and development of a country depends on its capability to provide the energy it needs. So far the majority of energy has been obtained from non-renewable sources, i.e. crude oil, natural gas and steam coal.

Different regions of the world differ in the amount of the deposits of raw materials. Additionally, they are prone to various political and weather risks. Local armed conflicts, social unrest or natural disasters result in considerable fluctuations in the supply of raw materials. The breakdown of the supply of a given raw material immediately affect its price on the spot market, which, in turn, influences the prices of other energy sources.

The aim of the article is to present the relations between the prices of the most important primary fuels on the European market in the period between October 2001 and May 2011. Causality between the prices will also be described. The identification of the mechanisms influencing prices on the raw material market will be conducted using the method of multiple time series analysis. The theoretical model of complementary commodities and prices was described in [13].

## 2. PRIMARY FUEL MARKET

### 2.1. The characteristics

Primary fuel and energy markets are of substantial importance in the proper functioning of the global economy. The most vital raw materials include crude oil, natural gas and coal, and they can be divided into two groups. One includes coal which is considered to be the most stable energy source thanks to its relatively large amounts and even distribution all over the world. It can be found on every continent, it is mined in several dozen countries, and international steam coal markets can reasonably expect stable supplies. The only region lacking in coal is the Near East. European deposits are quite large, but over half of them are located in Russia. Poland and Ukraine are also important coal producers in Europe.

The second group includes crude oil and natural gas, whose markets, unlike the coal market, are charactezized by high fluctuations and lower predictability. It is connected not only with their limited deposits, but also their location in the least stable regions of the world. The largest deposits of crude oil can be found in the Near East, Saudi Arabia, Central Asia, Venezuela, and Russia. The largest deposits of natural gas can be found in Russia and the Near East.

Europe lacks fuel resources and depends on their import. The use of main energy resources in Europe and Eurasia in 2010 amounted to 22,9% of the world consumption of crude oil, 35,8% of the world consumption of natural gas and only13,7% of the world consumption of coal.

### 2.2. Factors shaping prices

Factors shaping prices on primary fuel market can be divided into ones with a long-term influence and ones with a short-term influence.

Factors shaping coke prices on a short-term basis encompass e.g. weather, natural disasters, catastrophes or prolonged conflicts between employers and employees [7]. In the period analysed such factors included jams at Australian ports in June 2002, torrential rains and hurricanes in Australia and Indonesia at the turn of 2007/2008, problems with transport in the Republic of South Africa and Canada, blizzards in China as well as the flood in Australia in December 2010. Those factors caused problems with the supply of coal on international markets.

An important factor shaping crude oil prices is political stability of its main exporters. Any threat to this stability results in an immediate global increase of prices. Another essential factor is the present and predicted global economic conjuncture: the better predictions and world economic situation, the higher crude oil prices. Additionally, the increase in the demand for crude oil in the most highly populated and the most rapidly developing countries (China, India) exerts substantial influence on the crude oil market. Also, cartel agreements between crude oil producers belonging to OPEC (Organization of the Petroleum Exporting Countries), which specify the amount of production for the most important crude oil exporters are a factor influencing the market. What is more, the considerable drop of the American dollar value, which is the currency used in transactions, should not be neglected: to compensate for lower income the producers raise crude oil prices [12]. Taking into consideration all above mentioned factors, it is easy to account for considerable fluctuations of prices and uneasiness on the markets dealing with crude oil. Weather, natural disasters and catastrophes influence crude oil prices to the same extent as they do in case of coal prices. In the period analysed the actual factors shaping crude oil prices included e.g. Hurricane Ivan in September 2004, Hurricane Rita and Hurricane Katrina in August and September 2005, the strike in Venezuela in 2002, the American attack on Iraq in March 2003, guerrilla attacks on oil rigs in Nigeria in July 2008, and political conflicts in Tunisia, Egypt and Libya in 2011.

## 3. THE PRICES OF ENERGY SOURCES

On the world primary fuel markets some part of the turnover is realized in long-term contracts. Crude oil buyers are guaranteed the amount and the price. On the other hand, the producers are also guaranteed the price and sale. The remaining fuel is sold on the spot market depending on demand and supply. Price dynamics on this market considerably influences negotiated contract prices, and the other way round.

Spot market of steam coal uses so called price index, which plays an important informative function, as it presents the market from the point of view both of the exporter (FOB index – the price at the shipping point) and the importer (CIF index – the price at the destination port including insurance and fright). Most indices are developed by experts, and the most common ones include Argus, McCloskey, Platts and Global Coal.

As far as steam coal is concerned, the most important index on the European market is the price of coal exported from the Republic of South Africa set at the Port of Richards Bay (FOB RB) measured in $ per tonne and the price of imported coal set on the bases of CIF ARA (ports Amsterdam – Rotterdam - Antwerpia) also measured in $ per tonne.

The price of coal CIF ARA set by Argus [16] will be used to analyse the relations. The price index refers to transactions on the spot market with the delivery within 90 days. Using the information both from sellers and buyers, intermediary companies, and brokers, analysts set the weighted average mean of those prices for coal of a given quality. Next these prices are standarized and the price obtained this way refers to the standarized quality of coal (6000 kcal/kg). This price refers to NAR (net as received) and is expressed in American dollars for a tonne of coal of a given quality. Because prices refer to transactions concluded in the future (within 90 days), they can be treated as a kind of short-term forecasts.

The European gas market is dominated by long-term contracts, and only little amount of gas is sold at spot prices. Gas prices in long-term contracts depend on both the prices of crude oil and crude oil derived products on the world markets. The analyses will be based on Russian Natural Gas border price in Germany, measured in $ per a thousand cubic meters of gas [8].

Kinds of crude oil of different quality and availability are sold and bought on international markets. Crude oil prices on the spot market refer to three main indices for particular regions of the world. For the American market it is WTI, which is crude oil of a very high quality and low content of sulfur, for the Asian market it is Dubai Fateh, and for the European market it is the British crude oil Brent extracted in the North Sea and refined in Northern Europe.

Brent spot price FOB in $ per barrel will be used for the analysis of the price market.

## 4. METHODOLOGY

The basic model of the dynamics of a set of stochastic processes is the vector autoregressive model (VAR) in the form [14]:

$$y_t = \Phi D_t + A_1 y_{t-1} + \ldots + A_p y_{t-p} + u_t , \qquad (1)$$

where: $y_t = (y_{1t}, \ldots, y_{Kt})'$ is a vector of K time series, $D_t$ - contains deterministic variables (e.g. a linear trend, seasonality or other dummy variables), $\Phi$ - denotes the coefficient matrix for deterministic variables, $A_i$ - (KxK) - dimensional coefficient matrices of the model variables, $u_t = (u_{1t},...,u_{Kt})'$ - unobservable error vector which we assume to be a set of independent zero mean white noise processes with positive definite covariance matrix $E(u_t u'_t) = \Sigma_u$.

An interesting case of a VAR model appears when given time series are I(1) integrated, but there exists their linear combination which is stationary. The system variables are then in a long-run equilibrium, and the series are cointegrated. In this case, as it was shown by Granger in his famous Representation Theorem, cointegrated variables have a representation of a vector error correction model (VECM). In the model there is also a stationary component describing long-run equilibrium deviations [3]. The VEC model looks as follows (for simplicity reasons the deterministic part was omitted here):

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + ... + \Gamma_{p-1} \Delta y_{t-p+1} + u_t, \qquad (2)$$

where: $\Pi = -(I_K - A_1 - .. - A_p)$, $\Gamma_i = -(A_{i+1} + ... + A_p)$ for $i = 1,..., p-1$.

The model expressed by (2) can appear in the following three cases:

- $rk(\Pi) = K$ - $y_t$ process is stationary in variance,
- $rk(\Pi) = 0$ - long-run component in (2) disappears; the system of stable equations VAR should be built for the first differences,
- $0 < rk(\Pi) = r < K$ - there exists $r$ cointegrating relations for $y_t$ vector.

In empirical applications, in cases when some variables of $y_t$ vector are I(1), the key question concerns cointegration between them. It boils down to establishing a column rank of the matrix $\Pi$. Appropriate tests are performed sequentially. In $i$ step the null hypothesis is tested which states that $rk(\Pi) = i - 1$ against the hypothesis which states that $rk(\Pi) > i - 1$. The testing procedure ends in two cases: when there are no reasons to reject the null hypothesis and when the null hypothesis is rejected in step $K$ - 1. The most common statistics refer to the maximum eigenvalue statistics $\Pi$ or to its trace test and were published by [10,11].

The lag in vector autoregression models is chosen either using information criteria (usually *AIC, BIC, HQIC*) or in such a way as to minimize forecast MSE. Too low autoregression lag may cause crosscorrelations, while too high lag causes parameters to become statistically insignificant with further lags.

Statistical evaluation of the model consists of testing residual errors and model stability, for which the Jarque-Bera test and Doornik-Hansen test are used. To check residual autocorrelation, the following tests are used: Portmanteau test, Ljung-Box test, and Breusch-Godfrey test. Null hypotheses of those tests claim the lack of residual autocorrelation for the first $p$ lags. Their formulas can be found in [14].

Vector autoregression models allow for the analysis of Granger causality [6]. We can say that $y_{2t}$ vector is Granger cause for vector $y_{1t}$, if current values of $y_{1t}$ can be forecast more precisely using future values of vector $y_{2t}$.

## 5. VEC MODELS FOR ENERGY SOURCES

The analysis of the relations should be started by establishing the rank of integration for given equations of the system, i.e. the prices of crude oil, natural gas and steam coal. Taking into consideration observable variance growth, time price series were logarithmed. The functions of time series are presented in Figure 1.

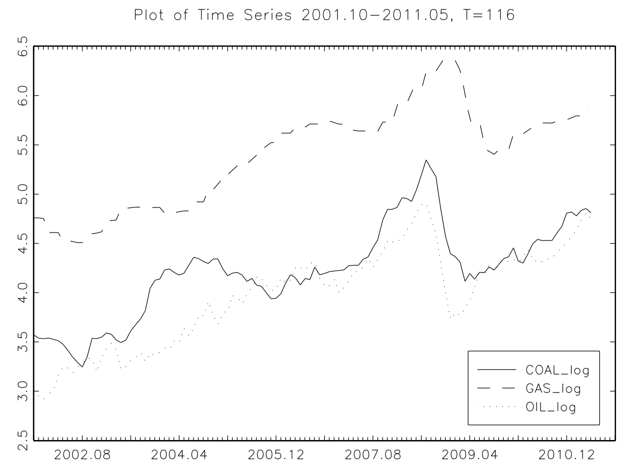


**Fig. 1.** Logarithmed prices of coal, gas and crude oil in the period October 2001 – May 2011
Source: Own calculations

Because of the visible growth of time series values, it has been decided that the model should contain a constant. ADF test results [2] are presented in Table 1. The number of lags in the test was established using AIC criterion.

All processes are integrated (I(1)), which allows for testing cointegration, i.e. long-run equilibrium between the prices of the main energy sources in Europe [4,15].

Assessing cointegration requires applying a sequence of Johansen trace tests [8], which may be sensitive to lags in multiple autoregression model. An additional difficulty is caused by the fact that information criteria do not yield unequivocal answer to the question concerning the optimal rank of VAR model (cf. Table 2).

Table 1
ADF test results for the values and the first differences

| Name of the variable | The value of test statistics ADF | The value of test statistics for differences |
|---|---|---|
| COAL_log | -1.7436 (1 lag) | -5.3387 |
| GAS_log | -1.6321 (6 of lags) | -3.6632 |
| OIL_log | -1.7947 (1 lag) | -5.8761 |

Source: Own calculations obtained using JMulti program. asymptotic critical values: $\alpha$ = 1% (-3.43); $\alpha$ =5% (-2.86); $\alpha$ = 10% (-2.57).

Table 2
Selection of optimal endogenous lags from information criteria

| Criterion | Optimal number of lags |
|---|---|
| Akaike Info Criterion | 10 |
| Final Prediction Error | 6 |
| Hannan-Quinn Criterion | 4 |
| Schwarz Criterion | 1 |

Source: Own calculations obtained using JMulti program.

Tables 3a and 3b present the results of Johansen test for a number of lags.

Table 3a
p- value of Johansen Trace Test for: COAL_log GAS_log OIL_log; number of lags 1 to 3

| Number of cointegration vectors | Rank of lags in VAR model | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 0 | 0.0000 | 0.0002 | 0.0000 |
| 1 | **0.5882** | **0.4830** | **0.4262** |
| 2 | 0.3800 | 0.2813 | 0.2689 |

Source: Own calculations obtained using JMulti program.

Table 3b
p - value of Johansen Trace Test for: COAL_log GAS_log OIL_log; number of lags 4 to 6

| Number of cointegration vectors | Rank of lags in VAR model | | |
|---|---|---|---|
| | 4 | 5 | 6 |
| 0 | 0.0000 | 0,0004 | 0,0005 |
| 1 | **0.6175** | **0,4145** | **0,5017** |
| 2 | 0.37 42 | 0,1883 | 0,4633 |

Source: Own calculations obtained using JMulti program.

In all cases the test indicates one cointegration vector. It can be said that prices of energy sources are in a long-run equilibrium, so a situation in which, in the long run, the price of one source considerably changes and does not trigger the reaction of other prices is impossible. Further analysis will consist of suggesting and verifying statistical correctness of models which differ in lags and take into account one cointegration vector. Due to editing requirements only the model with the best statistics will be presented here. It is worth mentioning, however, that models with relatively low number of lags displayed significant residual autocorrelation and residual heteroskedasticity (ARCH).

Tables 4a and 4b present the estimation of residuals of VEC Model with 6 lags, which indicates that even lags of 6 months influence the dynamics of the model. In residual autocorrelation tests 14 lags were assumed, and 5 lags were assumed for the multivariate ARCH-LM test.

Figure 2 shows residual crosscorrelation. The results obtained indicate the lack of residual autocorrelation.

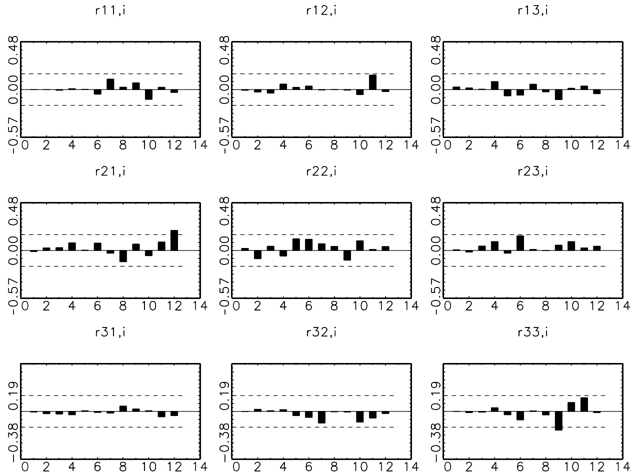


**Fig. 2.** Residual crosscorrelation
Source: Own calculations obtained using JMulti program

Table 4a
The value of statistics and p - value for residuals of VEC Model with 6 lags

| Residual autocorelation | |
|---|---|
| PORTMANTEAU TEST (H0:Rh=(r1,...,rh)=0) tested order: 14 test statistic: 84.0810 p-value: 0.1045 | LM-TYPE TEST FOR AUTOCORRELATION with 5 lags LM statistic: 57.8762 p-value: 0.0943 |

Source: Own calculations obtained using JMulti program.

Table 4b
The value of statistics and p - value for residuals of VEC Model with 6 lags

| TESTS FOR NONNORMALITY | MULTIVARIATE ARCH-LM TEST with 5 lags |
|---|---|
| Doornik & Hansen (1994) joint test statistic: 4.4040 p-value: 0.6222 | VARCHLM test statistic: 192.1389 p-value(chi^2): 0.2543 degrees of freedom: 180.0 |

Source: Own calculations obtained using JMulti program.

The results of the tests indicate that, at the acceptable level of significance, there is no reason for rejecting the hypothesis of residual normality, the lack of their autocorrelation, and the lack of ARCH.

So, the model can be used for estimating Granger causality. Table 5 presents p-value for Granger causality test.

Table 5
p-value for Granger causality test

| Cause | Result | p-value for Granger causality test |
|---|---|---|
| COAL_log | GAS_log, OIL_log | **0.1060** |
| GAS_log | COAL_log OIL_log | **0.2972** |
| OIL_log | COAL_log GAS_log | 0.0000 |
| GAS_log, OIL_log | COAL_log | **0.0565** |
| COAL_log OIL_log | GAS_log | 0.0000 |
| COAL_log GAS_log | OIL_log | 0.0295 |

Source: Own calculations obtained using JMulti program.

The results obtained indicate that:

- crude oil prices are Granger cause for the remaining two variables in the system,
- future prices of natural gas and coal considered separately do not allow for forecasting other pairs of variables,
- future prices of pairs of variables are significant for forecasting the third variable (the result of the test in which GAS_log and OIL_log are the cause is close to the level of significance 0.05).

Taking the above into consideration, it can be concluded that the variable triggering other changes in the system (the most important variable) is the price of crude oil. Future prices of crude oil help to predict the prices of remaining raw materials and can be treated as the causes of those changes. Past prices of natural gas, in turn, are not significant in forecasting the prices of crude oil and coal. Reactions of single variables to past prices of pairs are in all cases significant. In other words, pairs of variables carry aggregated information on the raw material market and are Granger causes for other prices of raw materials.

## 6. CONCLUSION

The paper deals with the analysis of a long-run equilibrium between the prices of non-renewable energy sources on the European market. As A. Ghoshray and B. Johnson [5] have shown, the time series of non-renewable energy prices (in the period of several dozens years) undergo structural changes. The authors of the paper decided to analyse cointegration for a relatively short period of 10 years on the European raw material market. The time of the analysis covers both a dynamic growth of prices between 2004 and 2008 and their dramatic drop after 2008. The results of the analysis reveal that in this period the prices of crude oil, natural gas and steam coal were in a long-run equilibrium. Market mechanisms make the prices increase together and decrease together in the long-run, which, one may be tempted to explain by fundamental factors (especially changing economic conjuncture) and weather (bitterly cold winter), both causing substantial changes in the demand for energy sources. However, it is contradicted by the analysis of Granger causality, which shows that the variables of the system should not be treated in the same way. The main cause of the changes in prices of non-renewable energy sources turned out to be the price of crude oil; its dominating role results from the fact that it is the major energy source in Europe (in 2009 it constituted almost 50% of the consumption of all non-renewable energy sources [1] and it is a product almost entirely sold on the spot market. That is why current prices of crude oil reflect the current situation on the market, which, in turn, is transferred to spot prices of the remaining non-renewable energy sources.

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## ANALIZA ZALEŻNOŚCI POMIĘDZY CENAMI PALIW PIERWOTNYCH NA EUROPEJSKIM RYNKU W LATACH 2001-2011

**Słowa kluczowe:** rynek paliw pierwotnych, przyczynowość w sensie Grangera, model VECM

**Streszczenie.** Celem referatu jest przedstawienie wzajemnych relacji pomiędzy cenami najważniejszych paliw pierwotnych (ropy, gazu ziemnego i węgla energetycznego) na rynku europejskim w okresie październik 2001-maj 2011. Warte odpowiedzi są pytania o przyczynowość występującą pomiędzy cenami. Identyfikacja mechanizmów oddziaływania cen na rynku surowców została prowadzona z wykorzystaniem metod analizy wielowymiarowych szeregów czasowych.
Wyniki analizy pokazały, że analizowane ceny znajdowały się w długookresowej równowadze, a więc w długim okresie ceny wspólnie rosną i wspólnie spadają. Można by przypuszczać, że jest to spowodowane czynnikami fundamentalnymi (koniunkturą gospodarczą) i pogodowymi, które powodują zmiany popytu nośników energii. Niemniej przeprowadzona analiza przyczynowości w sensie Grangera pokazuje, że nie można wszystkich zmiennych systemu traktować tak samo. Główną inspiracją zmian cen nośników energii nieodnawialnej okazały się ceny ropy naftowej. Przeszłe ceny ropy pomagają prognozować pozostałe ceny surowców i mogą być traktowane jako przyczyny tych zmian. Z kolei przeszłe ceny gazu ziemnego (węgla energetycznego) nie mają znaczenia dla prognozowania cen ropy i węgla (gazu).

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