# CORRELATION ANALYSIS OF THE CRUDE OIL, GOLD AND STEEL PRICES FOR THE PURPOSE OF AGRICULTURAL DEVELOPMENT

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ABSTRACT

This paper investigates the relationship between oil, gold and steel prices observed over a period of ten years with the aim of presenting their situation and trends using statistical methods and time series over a longer period of time and their impact on agricultural development. The high share of agriculture in the basic macroeconomic aggregates of the Republic of Serbia conditions that agriculture has a significant role in the foreign trade of the Republic of Serbia, especially in exports. The negative trend of rising fuel prices per farmer reduces the average fuel consumption per hectare. Also, the growth of the price of steel is conditioned by the growth of the prices of agricultural machinery.



## Introduction

Achieving energy efficiency of developed economies is conditioned by ensuring security of supply of raw materials in order to avoid shortages and reduce competitiveness

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(Avakumović et al., 2021; Leković et al., 2022). The price of raw materials is one of the most important factors in the structure of production costs and an indicator of the scarcity of these raw materials in a given market even in agriculture (Gleich et al., 2013; Vujović & Vujović, 2021). The properties of metals such as gold and steel and oil as strategic raw materials justify the economic importance of researching the mutual influence of their prices(Hooker, 2002; Mihajlović et al., 2020; Ristić et al., 2021).

The market for these metals and oil has evolved and reached a certain level of development and interaction. The value of these metals and oil has been expressed in dollars for the longest period of time, and for gold it is important to note that until the 1970s, the dollar was converted into gold. This convertibility has affected the economic stability of rare metal and oil prices, so that the cessation of convertibility will lead to a period of price instability even and agriculture products, which is still characterized by a trend of monitoring oscillations in the same direction (Simakova, 2011; Tekić et al., 2021).

## Methodology

In this paper, the price predictions of oil prices are correlated with the values of gold and steel prices from June 2008 to June 2018. This period at the very beginning includes the period of crisis in 2008, when the price of crude oil had a constant growth. In July of that year, the price of crude oil was 147.27 USD / bbl (Lang & Auer, 2019). Data on crude oil price movements used in this study refer to WTI crude oil prices on the New York Stock Exchange (NYMEX). The prices formed for the purchase of the nearest futures contract at the end of the working day were taken and are expressed in USD / bbl. Gold and steel prices were taken from the Macrotrends database. The number of observations is 2538 for each of these three resources. All data in this part of the analysis will be processed in the statistical program EVIEWS.

To select the models that best describe the movement of crude oil prices, methods of minimizing information criteria were chosen, specifically Akaike's, Schwarz's and Hannan-Quinn's information criteria, as well as the minimum standard error criterion, according to Kovacić (1995) and Mladenović and Nojković (2012). The information criterion is the sum of two components that react differently to changes in the number of model parameters (Dukić-Mijatović et al., 2021; Ilić & Tasić, 2021; Paspalj & Brzaković, 2021). Criteria for selecting the optimal set of explanatory variables, which is common for time series models, are the lowest values of the information criterion. In order to explain the time series, it is necessary to provide information about its basic properties. Prediction is based on the chosen model, but business in unstable economies should not be overlooked. It is recommended that, in addition to common sense, more models be used, as well as correlation and regression analysis, which are the basis of many statistical techniques (Savić & Obradović, 2020). Correlation and regression analyze the associations of different phenomena, which are represented by the values of two or more random variables. The association of random variables implies that changes in one variable are followed by changes in another variable. Correlation analyzes the strength and direction of the connection, while regression also analyzes the form of the connection, and also enables the prediction of the dependent variable based on the values of the independent variables (Chiroma et al., 2015; Mihajlović et al., 2018).

There are several tests to detect the order of differentiation, ie how many times a series needs to be differentiated to become stationary, but a graphical representation and correlations of series levels and first, second and third differences, minimum standard deviation and square root test will be used. Then, using the Durbin-Watson statistics, the existence of autocorrelation will be checked, that is, the correlation between the values of the time series at different time points.

**Gold price analysis**

The time series of gold prices is not a stationary series, which can be seen from its correlogram. From December 2008 until June 2011, the series has a tendency to grow, after which the decline and growth of data values alternate. The same conclusion about the non-stationarity of the series is made on the basis of the review.

**Table 1.** Choreogram of the gold price series

| | Autocorrelation | Partial correlation | Q- statistic | Probability |
|---|---|---|---|---|
| 1 | 0.997 | 0.997 | 2530.2 | 0.000 |
| 2 | 0.995 | 0.024 | 5049.2 | 0.000 |
| 3 | 0.993 | 0.016 | 7557.6 | 0.000 |
| 4 | 0.990 | -0.006 | 10055 | 0.000 |
| 5 | 0.988 | 0.021 | 12542 | 0.000 |
| 6 | 0.986 | -0.022 | 15019 | 0.000 |
| 7 | 0.983 | -0.006 | 17484 | 0.000 |
| 8 | 0.981 | 0.018 | 19939 | 0.000 |
| 9 | 0.979 | -0.016 | 22384 | 0.000 |
| 10 | 0.976 | -0.015 | 24817 | 0.000 |
| 11 | 0.974 | 0.042 | 27240 | 0.000 |
| 12 | 0.972 | 0.000 | 29654 | 0.000 |
| 13 | 0.970 | 0.029 | 32058 | 0.000 |
| 14 | 0.968 | 0.003 | 34453 | 0.000 |

*Source:* Authors' calculations(http://www.macrotrends.net/)

For that reason, it is necessary to differentiate the series in order to obtain a stationary series that can be modeled. The question is how many times it is necessary to differentiate this series in order to get its stationary presentation. There are several tests to detect the order of differentiation of a series. The following three are most often used in the literature(Popp et al, 2018):

1. graphic presentation of the original values of the series and its correlogram as well as graphic presentation of the first, second and third derivative of the series and their choreograms;
2. the method of minimum standard deviation and
3. the square root test.

It happens that these methods do not indicate the same order of differentiation, so the order of differentiation chosen from most methods is accepted.

**Table 2.** Choreogram of the first derivative of the gold price series

| | Autocorrelation | Partial correlation | Q- statistic | Probability |
|---|---|---|---|---|
| 1 | -0.024 | -0.024 | 1.501 | 0.221 |
| 2 | -0.021 | -0.022 | 2.617 | 0.270 |
| 3 | 0.015 | 0.014 | 3.176 | 0.365 |
| 4 | -0.024 | -0.024 | 4.615 | 0.329 |
| 5 | 0.033 | 0.032 | 7.356 | 0.195 |
| 6 | -0.007 | -0.007 | 7.477 | 0.279 |
| 7 | -0.028 | -0.026 | 9.487 | 0.220 |
| 8 | 0.026 | 0.023 | 11.180 | 0.192 |
| 9 | 0.040 | 0.042 | 15.216 | 0.085 |
| 10 | -0.051 | -0.049 | 21.911 | 0.016 |
| 11 | 0.000 | -0.002 | 21.911 | 0.025 |
| 12 | -0.034 | -0.035 | 24.921 | 0.015 |
| 13 | -0.001 | -0.001 | 24.924 | 0.024 |
| 14 | 0.031 | 0.024 | 27.377 | 0.017 |

*Source:* Authors' calculations(http://www.macrotrends.net/)

Based on Table 2, it can be concluded that the first derivative of the series is stationary, so it is necessary to differentiate the series only once. Another way to detect the order of differentiation of a series is the minimum standard deviation, which is presented in Table 3.

**Table 3.** Basic statistical indicators of series levels, first and second derivative

| | $X_t$ | $\Delta X_t$ | $\Delta^2 X_t$ |
|---|---|---|---|
| **Mean** | 1284.176 | 0.163633 | -0.003448 |
| **Median** | 1269.550 | 0.200000 | 0.000000 |
| **Max** | 1896.500 | 80.75000 | 204.0000 |
| **Min** | 692.5000 | -133.5000 | -124.2500 |
| **Standard deviation** | 234.9398 | 14.56025 | 20.84109 |
| **Coefficient of skewness** | 0.183270 | -0.648045 | 0.518382 |
| **Coefficient of kurtosis** | 2.895604 | 12.39897 | 11.08860 |
| | | | |
| **Jarque–Bera test** | 15.36024 | 9519.660 | 7032.412 |
| **Probability** | 0.000462 | 0.000000 | 0.000000 |
| | | | |
| **Number of observations** | 2538 | 2538 | 2538 |

*Source:* Authors' calculations

Table 3 presents the basic statistical indicators (mean, median, standard deviation, coefficient of kurtosis, which shows that it is flattened if less than 3 and the coefficient of skewness, which shows that it is asymmetric if it is greater than 0, etc.) price of gold $X_t$, the first derivative of the series price of gold $\Delta X_t$ as well as the second derivative of the series price of gold $\Delta^2 X_t$. According to the method of minimum standard deviation, it is necessary to differentiate the series once because the standard deviation of the series $\Delta X_t$ is the smallest (14.56025).

For the safety of the conclusion, it is necessary to conduct a square root test. In the square root test, zero and alternative (opposite assumptions) hypotheses will be set, which will be tested using one of three test statistics: $\tau_\mu$, $\tau_t$ or τ.(Rakić et al., 2021) The null and alternative hypotheses change from iteration to iteration during the square root test. In order to select the appropriate test statistics, the regression of the first derivative of the observed series to the constant is estimated, Table 4.

**Table 4.** Estimated regression $\Delta X_t$ on constant

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| C (constant) | 0.167901 | 0.288934 | 0.581103 | 0.5612 |
| $R^2$ (Coefficient of determination) | 0.000000 | **Mean of dependent variable ΔXt** | | 0.167901 |
| Adjusted $R^2$ | 0.000000 | **Standard deviation of dependent variable ΔXt** | | 14.55897 |
| Standard error of the regression | 14.55897 | **Akaike information criterion** | | 8.194686 |
| Residual Sum of Squares | 537963.7 | **Schwarz information criterion** | | 8.196985 |
| Durbin Watson Statistic | 2.048369 | **Hannan–Quinn information criterion** | | 8.195520 |

*Source:* Authors' calculations

Based on the results from Table 4, it can be seen that the constant in the observed regression is not statistically significant, ie that the trend at the series level is not statistically significant. For this reason, the τμ statistic test is used to test the unit root. The null hypothesis is set that the time series of gold prices $X_t$ has one unit root (order of differentiation d = 1) versus the alternative hypothesis that the time series $X_t$ is stationary (d = 0). The test statistic $\tau_\mu$ represents the t-ratio from the regression $\Delta X_t$ depending on the constant and $X_{t-1}$(Bampinas & Panagiotidis, 2015). The results of this regression are presented in Table 5.

**Table 5.** Estimated regression $\Delta X_t$ depending on the constant and $X_{t-1}$

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| C (konstanta) | 3.403252 | 1.602897 | 2.123188 | 0.0338 |
| $X_{t-1}$ | -0.002520 | 0.001228 | -2.052010 | 0.0403 |
| $R^2$ (Coefficient of determination) | 0.001657 | **Mean of dependent variable ΔXt** | | 0.167901 |
| Adjusted $R^2$ | 0.001263 | **Standard deviation of dependent variable ΔXt** | | 14.55897 |
| Standard error of the regression | 14.54977 | **Akaike information criterion** | | 8.193815 |
| Residual Sum of Squares | 537072.3 | **Schwarz information criterion** | | 8.198415 |
| F-Statistic | 4.210744 | **Hannan–Quinn information criterion** | | 8.195484 |
| Probability (F-Statistic) | 0.040271 | **Durbin Watson Statistic** | | 2.046604 |

*Source:* Authors' calculations

Statistic $\tau_\mu$=-2.052010 is compared to the critical value $\tau_\mu^k$ obtained according to the formula: $\tau_\mu = -2.8621 - \frac{2.738}{T} - \frac{8.36}{T^2}$ (1)

where T represents the number of observations, in our case 2538. Based on formula (1), $\tau_\mu^k$ = -2.863201 was calculated. Since $\tau_\mu^k$ is less than the calculated value of $\tau_\mu$, it is concluded that the time series $X_t$ has one unit root, ie the null hypothesis is accepted. In the following, it is necessary to check whether the time series has more than one unit root, so the null hypothesis is set that the time series $X_t$ has two unit roots compared to the alternative hypothesis that $X_t$ has one unit root. Test statistics were obtained based on the corresponding t-ratio from the estimated regression $\Delta^2 X_t$ to constant and $\Delta X_{t-1}$, Table 6.

**Table 6.** Estimated regression $\Delta^2 X_t$ depending on the constant and $\Delta X_{t-1}$

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| **C (konstanta)** | 0.167692 | 0.289007 | 0.580236 | 0.5618 |
| **$X_{t-1}$** | -1.024298 | 0.01985 | -51.602990 | 0.0000 |
| **$R^2$ (Coefficient of determination)** | 0.512202 | **Mean of dependent variable ΔXt** | | -0.003448 |
| **Adjusted $R^2$** | 0.512009 | **Standard deviation of dependent variable ΔXt** | | 20.84109 |
| **Standard error of the regression** | 14.55882 | **Akaike information criterion** | | 8.195059 |
| **Residual Sum of Squares** | 537528.7 | **Schwarz information criterion** | | 8.199660 |
| **F-Statistic** | 2662.868 | **Hannan–Quinn information criterion** | | 8.196728 |
| **Probability (F-Statistic)** | 0.000000 | **Durbin Watson Statistic** | | 2.007082 |

*Source:* Authors' calculations

Statistics $\tau_\mu$ = -51.60299 are compared with the critical value $\tau_\mu^k$ = -2.863201, where it is concluded that the null hypothesis is rejected, ie it is confirmed that the time series of gold prices, $X_t$ must be differentiated once. So, the first derivative of the gold price series is modeled below. In order to determine the AR and MA components of the first derivative of the series, the choreogram of the first derivative is reviewed, Table 2 and it is concluded that it is a series of "white noise". The gold price series can be modeled as ARIMA (0,1,0):

$$\Delta X_{t-1} = e_t \quad (2)$$

According to McNeil at al (2005) and Francq at al (2010), white noise is a random component, which with deterministic components forms time series. White noise is very important, because, based on it, much more complex stationary processes have been built. In addition to the fact that white noise is a random component, its properties are that it is uncorrelated, as well as that it is poorly stationary.

**Steel price analysis**

Time series analysis is based on stationary assumptions. Stationarity implies that the moments of the series are constant over time. If there are structural fractures in the series, the values of these moments change at certain time points (on a specific date or dates). In this particular case, the effect of structural fractures will be analyzed using regression with structural fractures based on the Bai-Perron approach. This is a test for multiple fractures (more than one structural fracture in a series) that are not known in advance and that it is necessary to identify and determine their dates with a model.

The analysis included a series of steel prices from April 1991 to June 2018. Thus, in the observed period, after the absence of the trend and then the fall in the price of steel, their rapid growth occurred from the end of 2003 until the middle of 2008, when the price of steel reached its maximum. This trend can be explained by developments in financial markets when investors face rising volatility in the price of securities (stocks and bonds) and insufficiently attractive yields, which shifts their demand towards commodity markets, including the metal market. As a result, there is a growing demand for steel on world markets, as a result of which the prices of this metal are skyrocketing so that, from mid-2008 and in the next six months, they return to almost the same level as before the crisis. However, in the period after the outbreak of the global financial crisis, their volatility is much more pronounced and is evident until the end of the observed period.

Considering the described dynamics of the time series of steel prices, as well as on the basis of the review of its correlogram (Table 7), the conclusion is that it is a non - stationary time series.

**Table 7.** Correlogram of the steel price series

| | Autocorrelation | Partial correlation | Q-statistics | Probability |
|---|---|---|---|---|
| 1 | 0.998 | 0.998 | 6821 | 0.000 |
| 2 | 0.997 | 0.009 | 13622 | 0.000 |
| 3 | 0.995 | -0.010 | 20403 | 0.000 |
| 4 | 0.994 | 0.036 | 27165 | 0.000 |
| 5 | 0.992 | -0.008 | 33909 | 0.000 |
| 6 | 0.991 | -0.007 | 40633 | 0.000 |
| 7 | 0.989 | -0.037 | 47337 | 0.000 |
| 8 | 0.988 | -0.013 | 54020 | 0.000 |
| 9 | 0.986 | 0.046 | 60684 | 0.000 |
| 10 | 0.985 | 0.002 | 67329 | 0.000 |
| 11 | 0.983 | -0.041 | 73953 | 0.000 |
| 12 | 0.981 | -0.069 | 80554 | 0.000 |
| 13 | 0.980 | -0.008 | 87132 | 0.000 |
| 14 | 0.978 | 0.012 | 93686 | 0.000 |

*Source:* Authors' calculations(http://www.macrotrends.net/)

Since the procedure for identifying structural fractures in the series involves the prior construction of the AR (1) model, it is necessary to logarithm the observed series of steel prices, which achieves homogeneity of variance. Only after that it is possible to test the hypothesis of the existence of a unit root. In the formal expression AR (1) the model can be represented as follows:

$$y_t = \alpha + \beta y_{t-1} + \varepsilon_t \tag{3}$$

where α and β are the parameters of the model, while εt denotes the process of white noise, as a series of uncorrelated random variables of zero mean value and constant variance. The stationarity of the series implies that the parameters of the α and β models are constant over time. However, in the case of a structural break in the series, at least one of these parameters changes value on a certain date during the observed time period. Based on the conducted unit root test, it can be concluded that this is a non-stationary series. Table 8 shows the output of the test.

**Table 8.** Results of the ADF test of the logarithmic series of steel prices

| | | | | |
|---|---|---|---|---|
| Zero hypothesis: LNSTEEL *has a unit root* | | | | |
| Exogenous: Constant | | | | |
| *Lag Length*: 0 (Automatic - based on SIC, maxlag=34) | | | | |
| | | | **t-Statistics** | **Probability** |
| **Dickie-Fuller test statistics** | | | -2.454314 | 0.1270 |
| **Critical value test** | 1% level | | -3.431128 | |
| | 5% level | | -2.861769 | |
| | 10% level | | -2.566934 | |

*Source:* Authors' calculations(http://www.macrotrends.net/)

By differentiating the logarithmic series, its stationarity is achieved, however, the presence of structural fractures in the series must not be abstracted in the modeling of this series. By neglecting the existence of structural fracture in the series, an overestimated estimate of the variance of the time series is obtained, while the estimates of ordinary and partial autocorrelation coefficients are biased. Also, the obtained forecasts are unreliable.

**Table 9.** ADF test results of the AR (1) model

| | | | | |
|---|---|---|---|---|
| Increased Dicky-Fuller test equation | | | | |
| Dependent variable: D(LNSTEEL) | | | | |
| Least squares method | | | | |
| Sample: 4/15/1991 6/12/2018 | | | | |
| Number of observations: 6838 | | | | |
| **Variable** | **Coefficient** | **Standard error** | **t-StatisticS** | **Probability** |
| LNSTEEL(-1) [β] | -0.001688 | 0.000688 | -2.454314 | 0.0141 |
| C [α] | 0.005638 | 0.002268 | 2.486587 | 0.0129 |
| **$R^2$ (Coefficient of determination)** | 0.000880 | **Mean of dependent variable ΔXt** | | 0.000150 |
| **Adjusted $R^2$** | 0.000734 | **Standard deviation of dependent variable ΔXt** | | 0.031132 |

| | | | |
|---|---|---|---|
| **Standard error of the regression** | 0.031121 | **Akaike information criterion** | -4.101571 |
| **Residual Sum of Squares** | 6.620807 | **Schwarz information criterion** | -4.099573 |
| **F-Statistic** | 6.023655 | **Hannan–Quinn information criterion** | -4.100882 |
| **Probability (F-Statistic)** | 0.014140 | **Durbin Watson Statistic** | 1.989327 |

*Source:* Authors' calculations

Based on the results shown in Table 9, it can be seen that the segment on the ordinate, ie, the constant (α) and the parameter with the independent variable (β) are statistically significant. Namely, at the level of significance of 5%, the hypothesis that the parameters of the observed AR model are equal to zero was rejected. The next step is to identify the structural fracture, ie. fractures in series.

The Quantum-Andrews test starts from the assumption that a priori the period of structural fracture is not known, and therefore the existence of fracture in one or more time periods in the sample is studied. The corresponding null hypothesis assumes the absence of refraction. The basis of the test is to perform a single Cau (Chow) test at each point along the interval [λT, (1-λ) T]. After that all n test statistics of Cau tests are summarized and supremum F statistics are performed.

$$sup\ F \ = \ sup_{\tau ò [\lambda T,\ (1-\lambda)T]} F\ , \qquad t = 1, 2, \ldots, T \qquad (4)$$

where τ is the breaking date, while λ is the trimming parameter. The truncation parameter (λ) is used because the distribution of statistics (equation above) becomes distorted as it approaches the beginning (λT) or end (1-λ) T] of the sample. For this reason, it is usually suggested that the first λT and last λT of the observed sample not be included in the testing process. As with the Cau test and the Quantum-Andrews test (1960, 1993), the null hypothesis that there is no structural fracture is rejected if the minimum F statistic is greater than the critical value.

In this particular case, a shortening parameter of 15% was selected. The procedure compared 4787 breakpoints. The results of the Quantum-Andrews test (1960, 1993) are given in Table 10.

**Table 10.** Quandt-Andrews test results

<table>
<tr><td colspan="3">Null hypothesis: There is no breakpoint in the cut 15% of the data</td></tr>
<tr><td colspan="3">Sample equation: 4/15/1991 6/12/2018</td></tr>
<tr><td colspan="3">Test sample: 5/04/1995 5/08/2014</td></tr>
<tr><td colspan="3">Number of compared values: 4787</td></tr>
<tr><th>Statistics</th><th>Value</th><th>Probability</th></tr>
<tr><td>Maximum LR F-statistics (6/26/2008)</td><td>9.735230</td><td>0.0015</td></tr>
<tr><td colspan="3">Note: the probability is calculated using Hansen's method (1997)</td></tr>
</table>

*Source:* Authors' calculations

The maximum value of the Cau test was determined for the time point on June 26, 2008. and it is statistically significant considering that the obtained value of the statistical significance test is less than 1% (p = 0.15%). This specifically means that the hypothesis that there is no structural break in the series was rejected. In the further course of the analysis, the Bai-Peron test (1998, 2003) will be performed, since the visual inspection of the series shows the existence of at least three different regimes in the movement of the observed series. The Bai-Peron test (1998, 2003) starts from the following model with multiple fractures:

$$y_t = x_t^{,}\beta + z_t^{,}\delta_1 + u_{t^,} = 1,\ldots,T_{1,},$$

$$y_t = x_t^{,}\beta + z_t^{,}\delta_2 + u_{t^,} = 1,\ldots,T_{2,}, \qquad (5)$$

…………………………………...

$$y_t = x_t^{,}\beta + z_t^{,}\delta_{m+1} + u_{t^,} = T_m + 1,\ldots,T$$

where $y_t$ is the dependent variable at time t (steel price), $X_t'$ i $Z_t'$ predictor vectors, while β and $\sigma_j$ are the corresponding coefficient vectors, and the error component. It is, in fact, a system of simultaneous equations, in which only $\sigma_j$ coefficients are variable. Thus, based on the calculated Double maximum tests, $UD_{max}$ and $WD_{max}$, the initial hypothesis should be tested, which reads:

$$H_0:\ \sigma_j = \sigma_0 \qquad \text{za } j = 1,\ldots,m. \qquad (6)$$

In other words, we should test the hypothesis that the regression coefficients are constant, that is, that they do not change during the observed period, as opposed to the alternative that at least one coefficient varies with the passage of time. Also, the application of the Bai-Peron test (1998, 2003) implies that the time points of refraction ($T_1$, ..., $T_m$) are treated as unknown and estimated together with unknown coefficients on a sample of size T. Estimates of the coefficients β and $\sigma_j$ were obtained by the method of least squares by minimizing the sum of the squares of the residue in the label $S_T(\hat{T}_{1,\ldots,}\hat{T}_m)$, while the estimated breakpoints are obtained as:

$$(\hat{T}_{1,\ldots,}\hat{T}_m) = \arg\min_{(T_1,\ldots,T_m)} S_T(T_1,\ldots,T_m) \qquad (7)$$

Table 11 shows the results of the application of the Bai-Peron test (1998, 2003) on the example of the observed series of steel prices.

**Table 11.** Bai-Perron test results

| | | | |
|---|---|---|---|
| Breakpoint specification | | | |
| Breakpoint description used in the estimation | | | |
| Equation: EQ_BP | | | |
| Summary | | | |
| Estimated number of interruptions: 3 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Method: Bai-Peron test from 1 to M globally determined fractures | | | | | |
| Maximum number of fractures: 5 | | | | | |
| Fractures: 11/18/1999, 12/18/2003, 8/05/2011 | | | | | |
| Current breakpoint calculations | | | | | |
| Multiple fracture tests | | | | | |
| Bay-Peron test from 1 to M globally determined fractures | | | | | |
| Sample: 4/15/1991 6/12/2018 | | | | | |
| Number of observations included: 6838 | | | | | |
| Fracture variables: C | | | | | |
| Pause test option: Trimming 0.15, Maximum number of breaks 5, Sig. level 0.05 | | | | | |
| Test of statistically used HAC covariance | | | | | |
| Enable the distribution of heterogeneous errors over interrupts | | | | | |
| *UDmax set pauses:* | | | | 3 | |
| *WDmax set pauses:* | | | | 3 | |
| | | Scaled | Multiplied | Critical | |
| **Fractures** | **F-statistics** | **F- statistics** | **F- statistics** | **Value** | |
| 1 | 5.438704 | 5.438704 | 5.438704 | 8.58 | |
| 2 * | 26.94498 | 26.94498 | 32.02049 | 7.22 | |
| 3 * | 29.49239 | 29.49239 | 42.45716 | 5.96 | |
| 4 * | 14.67708 | 14.67708 | 25.23634 | 4.99 | |
| 5 * | 12.17317 | 12.17317 | 26.71248 | 3.91 | |
| *UDMax* statistics* | | 29.49239 | *UDMax* critical value** | | 8.88 |
| *WDMax* statistics* | | 42.45716 | *WDMax* critical value** | | 9.91 |
| * Significant at 0.05 level. | | | | | |
| ** Bai-Peron (Econometric Journal, 2003) critical values. | | | | | |

*Source:* Authors' calculations

Based on the results of the Bai-Perón test (1998, 2003), it was determined that the series has three statistically significant structural break dates (November 18, 1999, December 18, 2003 and August 5, 2011) which define four different regimes. steel price movements.

None of these dates correspond to the originally determined fracture date according to the Quantum-Andrews test (June 26, 2008). However, it should be borne in mind that tests such as the Quantum-Andrews test (tests to check for breakage in a series and when no break date is known in advance) can identify and evaluate only one break date in a series, which is a serious limitation. For that reason, the interpretation of the results of the Quantum-Andrews test should be reduced exclusively to checking whether there is a structural fracture in the series, after which the Bai-Peron test should confirm this finding, and then identify fractures in the series and determine their statistical significance(Kanjilal & Ghosh, 2017).

## Crude oil price analysis

Over the last 60 years, large fluctuations in crude oil prices have often occurred. Although the market for all goods is determined by supply and demand, the crude oil market has a political factor as a reflection of changes in power relations on the global geopolitical scene. For that reason, predicting the movement of oil prices is not a thankful task(Simić et al., 2021), because it is necessary in a certain way, using different models and methods, and based on the movement of crude oil prices in the past, to predict future price movements. Crude oil prices sometimes show sharp jumps and then sharp falls, which are the characteristics of major crises. After that period, they generally remain at a higher level than before the sudden jump(Aguilera & Radetzki, 2017).

The time series of crude oil prices is also non-stationary, which is confirmed by its correlogram (Table 12). The price of crude oil at the beginning of the observed period has the highest value (about 140 USD / bbl) since when it constantly begins to decline and in 8 months reaches a value of about 30 USD / bbl. The reason may be political in nature and some manipulations in the global market. Since February 2009, the price of crude oil has been constantly rising, but it no longer reaches the high value as at the beginning of the observed period. From the end of May 2014, the price of crude oil has been constantly falling again until the beginning of February 2016, when it reached a value of around 25 USD / bbl. The reasons may be similar to 2008.

**Table 12.** Correlogram of the time series of crude oil prices

| | Autocorrelation | Partial correlation | Q-statistics | Probability |
|---|---|---|---|---|
| 1 | 0.996 | 0.996 | 2517.1 | 0.000 |
| 2 | 0.993 | 0.032 | 5017.7 | 0.000 |
| 3 | 0.989 | -0.001 | 7501.8 | 0.000 |
| 4 | 0.986 | -0.003 | 9969.3 | 0.000 |
| 5 | 0.982 | -0.030 | 12419 | 0.000 |
| 6 | 0.979 | 0.028 | 14853 | 0.000 |
| 7 | 0.975 | -0.038 | 17269 | 0.000 |
| 8 | 0.971 | 0.023 | 19669 | 0.000 |
| 9 | 0.968 | -0.009 | 22051 | 0.000 |
| 10 | 0.964 | -0.025 | 24416 | 0.000 |
| 11 | 0.960 | -0.003 | 26764 | 0.000 |
| 12 | 0.956 | -0.001 | 29094 | 0.000 |
| 13 | 0.952 | -0.042 | 31405 | 0.000 |
| 14 | 0.948 | -0.037 | 33696 | 0.000 |

*Source:* Authors' calculations

Based on Table 12, it is clear that the time series of crude oil prices needs to be differentiated in order to obtain a stationary time series that can be modeled. The question of the order of differentiation that can be detected on the basis of the above-mentioned tests arises. By reviewing the choreogram of the first derivative of the series of crude oil prices, it can be concluded that the first derivative achieves stationarity in the series (Table 13).

**Table 13.** Correlogram of the first difference of the time series of crude oil prices

| | Autocorrelation | Partial correlation | Q-statistics | Probability |
|---|---|---|---|---|
| 1 | -0.048 | -0.048 | 5.781 | 0.002 |
| 2 | -0.022 | -0.025 | 7.0467 | 0.030 |
| 3 | 0.042 | 0.040 | 11.550 | 0.009 |
| 4 | 0.017 | 0.020 | 12.251 | 0.016 |
| 5 | -0.058 | -0.055 | 20.8660 | 0.001 |
| 6 | 0.053 | 0.047 | 27.894 | 0.000 |
| 7 | -0.018 | -0.017 | 28.697 | 0.000 |
| 8 | -0.028 | -0.023 | 30.683 | 0.000 |
| 9 | 0.027 | 0.022 | 32.496 | 0.000 |
| 10 | 0.000 | -0.003 | 32.497 | 0.000 |
| 11 | -0.018 | -0.009 | 33.326 | 0.000 |
| 12 | 0.045 | 0.039 | 38.517 | 0.000 |
| 13 | 0.037 | 0.038 | 41.912 | 0.000 |
| 14 | -0.037 | -0.027 | 45.435 | 0.000 |

*Source:* Authors' calculations

**Table 14.** Basic statistical indicators of the level, first and second derivative of the time series of crude oil prices

| | $X_t$ | $\Delta X_t$ | $\Delta^2 X_t$ |
|---|---|---|---|
| **Mean** | 74.27978 | -0.026780 | 0.000253 |
| **Median** | 76.37000 | 0.030000 | -0.030000 |
| **Max** | 145.3100 | 18.56000 | 14.89000 |
| **Min** | 26.21000 | -14.76000 | -33.32000 |
| **Standard deviation** | 23.62546 | 1.650751 | 2.389628 |
| **Coefficient of skewness** | 0.059205 | -0.054434 | -0.794004 |
| **Coefficient of kurtosis** | 1.981827 | 14.34224 | 20.78302 |
| | | | |
| **Jarque–Bera test** | 110.8048 | 13568.08 | 33615.65 |
| **Probability** | 0.000000 | 0.000000 | 0.000000 |
| | | | |
| **Number of observations** | 2531 | 2531 | 2531 |

*Source:* Authors' calculations

If we observe the standard deviations of the level of the time series of crude oil prices, its first and second derivative, it can be concluded that the first standard deviation of the time series of crude oil prices, 1.650751, has the smallest standard deviation (Table 14). Therefore, this criterion also points to the conclusion that the time series of crude oil prices needs to be differentiated once. Of course, this conclusion must be verified by a unit root test. First, it is hypothesized that the time series of crude oil prices $X_t$ has one unit root compared to the alternative hypothesis that time series $X_t$ is stationary. The $\tau_\mu$ statistic is used for testing because the regression constant $\Delta X_t$ on the constant is not statistically significant (Table 15).

**Table 15.** Estimated regression of the first derivative of the series of crude oil prices depending on the constant

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| C (constant) | -0.026979 | 0.032800 | -0.822524 | 0.4109 |
| $R^2$ (Coefficient of determination) | 0.000000 | Mean of dependent variable ΔXt | | -0.026979 |
| Adjusted $R^2$ | 0.000000 | Standard deviation of dependent variable ΔXt | | 1.650455 |
| Standard error of the regression | 1.650455 | Akaike information criterion | | 3.840374 |
| Residual Sum of Squares | 6894.450 | Schwarz information criterion | | 3.842679 |
| Durbin Watson Statistic | 2.095469 | Hannan–Quinn information criterion | | 3.841211 |

*Source:* Authors' calculations

**Table 16.** Estimated regression $\Delta X_t$ depending on the constant and $X_{t-1}$

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| C (constant) | 0.246748 | 0.107944 | 2.285888 | 0.0223 |
| X(-1) | -0.006383 | 0.001384 | -2.661348 | 0.0078 |
| $R^2$ (Coefficient of determination) | 0.002792 | Mean of dependent variable ΔXt | | 0.026979 |
| Adjusted $R^2$ | 0.002398 | Standard deviation of dependent variable ΔXt | | 1.650455 |
| Standard error of the regression | 1.648476 | Akaike information criterion | | 3.838369 |
| Residual Sum of Squares | 6875.203 | Schwarz information criterion | | 3.842979 |
| F-statistic | 7.082772 | Hannan–Quinn information criterion | | 3.840041 |
| Probability (F-statistic) | 0.007832 | Durbin Watson Statistic | | 2.093611 |

*Source:* Authors' calculations

The statistics $\tau_\mu$ is equal to -2.661348 (Table 16) and is higher than the critical value $\tau_\mu^k$ = -2.8632, so the null hypothesis is not rejected and it is concluded that the time series of crude oil prices has one unit root. The test statistic $\tau_\mu$ is equal to -52.75178 (Table 17) and is less than the critical value $\tau_\mu^k$ = -2.8632, so the null hypothesis is rejected and it is confirmed that the observed time series has only one unit root.

**Table 17.** Estimated regression $\Delta^2 X_t$ depending on the constant and $\Delta X_{t-1}$

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| C (konstanta) | -0.028071 | 0.032786 | -0.856194 | 0.3920 |
| DX(-1) | -1.047755 | 0.019862 | -52.75178 | 0.0000 |

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| $R^2$ (Coefficient of determination) | 0.523886 | Mean of dependent variable ΔXt | | 0.000253 |
| Adjusted $R^2$ | 0.523697 | Standard deviation of dependent variable ΔXt | | 2.389628 |
| Standard error of the regression | 1.649194 | Akaike information criterion | | 3.839240 |
| Residual Sum of Squares | 6878.474 | Schwarz information criterion | | 3.843852 |
| F-statistic | 2782.750 | Hannan–Quinn information criterion | | 3.840913 |
| Probability (F-statistic) | 0.000000 | Durbin Watson Statistic | | 2.001033 |

*Source:* Authors' calculations

In the following, the first derivative of the time series of crude oil prices is modeled based on the observation of the correlogram of the same (Table 13). The choreogram referred to several ARIMA models, of which the ARIMA model (6,1,1) was chosen because it was the best according to the criterion of minimum standard error and minimum Akaike information criterion. The estimated model is presented in Table 18 and has the form:

$$\Delta X_t = 0.0392\Delta X_{t-3} - 0.0541\ \Delta X_{t-5} + 0.0479\ \Delta X_{t-6} + e_t - 0.0415 e_{t-1} \quad (8)$$

**Table 18.** Estimated ARIMA model (6,1,1) for the crude oil price series

| | Coefficient | Standard error | t-Statistic | Probability |
|---|---|---|---|---|
| AR(3) | 0.039250 | 0.019852 | 1.977080 | 0.0481 |
| AR(5) | -0.054090 | 0.019800 | -2.731844 | 0.0063 |
| AR(6) | 0.047924 | 0.019811 | 2.419075 | 0.0156 |
| MA(1) | -0.041466 | 0.019902 | -2.08356 | 0.0373 |
| $R^2$ (Coefficient of determination) | 0.008808 | Mean of dependent variable ΔXt | | -0.027823 |
| Adjusted $R^2$ | 0.007629 | Standard deviation of dependent variable ΔXt | | 1.647768 |
| Standard error of the regression | 1.641471 | Akaike information criterion | | 3.830645 |
| Residual Sum of Squares | 6795.344 | Schwarz information criterion | | 3.839884 |
| Durbin Watson Statistic | 1.997284 | Hannan–Quinn information criterion | | 3.833997 |

*Source:* Authors' calculations

Based on the evaluated model, it can be concluded that the price of crude oil at the observed moment (observed day) depends on the prices formed in the last seven days as well as random fluctuations in the market of the observed and previous day. For that reason, it is not possible to forecast the price of crude oil for a longer period of time, that is, the best results are in the prediction of the movement of crude oil prices in just one day.

## Conclusion

The correlation between gold and crude oil is complex. Gold is an asset that is often used as a hedge against risk, an asset that preserves the value of assets and whose price depends largely on sensitive markets and inflationary developments. While crude oil is a risky raw material and its price depends on the balance that exists in the market between supply and demand for this resource. Crude oil and gold depend on and are largely conditioned by economic growth over time, but given that oil is the most sought after raw material and gold the most sought after precious metal, they play an important role in shaping the economy, even in agriculture. These means may show that there is a significant correlation, but it does not necessarily mean that they affect each other. Viewed through the analyzed period from 2008 to 2017, it can be noticed that there were time periods where the correlation was significant, as well as periods such as in the first quarter of 2016, when the price of gold rose by about 21%. During that period, the correlation between crude oil and gold was the lowest in that year, at -39%. The correlation was negative, because due to the fall in oil prices and the impact of fear on the global market, gold prices increased. Thus, a significant correlation may exist, but it does not have to be due to the influence of one good on another, but can be expressed as a result of some other variables, which may be common to both goods. The main conclusion is that the general level of gold prices is developing in the same direction as crude oil prices, but it should not be taken as relevant data for a longer period of time, although short-term patterns are emerging.

Agricultural production in which a significant amount of energy is invested depends on their price and availability to agricultural producers. In the observed period, the change in the price of crude oil significantly affected the reduction or growth of agricultural production, which was reflected in the total GDP of the country.

How important steel is for everyday life can be seen from the United States Geological Survey (USGS) on steel production and its impact on the global economy. According to their research, steel is the fourth most sought after metal in the world. In 2017, the largest steel producer in the world is China with about 843 million tons, followed by Japan with about 104 million tons, India with 99 million tons, the United States with 82 million tons, etc. In addition, the research results indicate that the two variables, crude oil prices and steel prices, have a cointegration effect. Time series have the property of cointegration, if the time series are non-stationary, and their linear combination is stationary. This property is important because economic time series move unpredictably over time, that is, they have a stochastic trend. Changes in the price of steel cause an increase in the prices of agricultural machinery, which significantly increases the costs of agricultural production. In a longer period of time, it reduces yields and total income on the basis of agricultural production.

### Conflict of interests

The authors declare no conflict of interest.

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