SHORT-TERM AND LONG-TERM RELATIONSHIPS BETWEEN GOLD PRICES AND OIL PRICES

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Abstract: *This article focuses on the econometric analysis of the prices of oil and gold. The aim is to determine the degree and nature of the investigated commodity dependence in terms of short-term and long-term relationships. The work contains basic characteristics, determinants of price development and theoretical description of statistical tools used to analyze dependencies of investigated time series. In the practical part of the article there is given its own analysis and final interpretation of the development of studied commodities. There are used methods of correlation and regression analysis, Granger causality, Augmented Dickey-Fuller test of stationarity, Johansen test. With respect to Engle-Granger test the two variables have a long run equilibrium relationship. Moreover, the Granger causality test reveals that in long-term, the change in prices of gold influences the change in prices of oil, while the chance in prices of oil does not influence the future change in prices of gold. For time series analysis (monthly average commodity prices, April 1983 – December 2016) there was used computer program GRETL.*

Keywords: *ADF Test of Stationarity, Correlation Analysis, Granger Causality, Regression Analysis, Time Series Analysis, VECM Model.*

JEL Classification: *C13, C22.*

Introduction

Nowadays, markets and economies of individual countries are not isolated. Globalization and deregulation have an important role in the integration process. Mutual interconnection of markets also applies to commodity markets, the important representatives of which are oil and gold. Gold and oil, as the most marketable commodities, play a significant role in shaping the economy and therefore their relationship is important.

The aim of the work is to determine the extent and nature of the interconnection between the price levels of oil and gold in terms of short and long-term relationships using statistical and econometric models. The core of the article is to determine, whether there is a long-term relationship between the commodities, namely whether the prices of gold and oil are co-integrated. Prices of gold and oil are quoted in US dollars. Co-integration tests are studied by the authors (Blake and Fomby, 1997), (Enders and Granger, 1998) and (Enders and Siklos, 2001) in their articles.

The paper is organized as follows. The next section briefly summarizes the existing literature related with the topics in this paper. Section ‘‘Characteristics of the commodities” presents commodity: gold and oil. Then, section ‘‘Analysis of the relationship between gold and oil prices’’ provides the empirical study and policy implications of this paper, which mainly includes the testing Granger causality. The next section presents testing the long-term relationship between the gold prices and oil prices. Finally, some concluding remarks are put forward in the last section.

1 Literature review

There is an interesting study by Radomský (2012), who argues that price levels of gold and oil are highly correlated. In his article, he examines weekly data, claiming that a higher weekly oil price level may not affect the weekly gold price level in terms of a long-term analysis. Similar results were obtained for daily, monthly and quarterly values.

Comparison of the development of oil and gold prices in the period 1968-2009 was also performed by Mielcová (2009). In her article, she states that one co-integration relationship was confirmed, which argues that changes in the price of gold affect future changes in the price of oil.

The authors (Narayan, Narayan, and Zheng, 2010) investigated long-term correlations between gold prices and oil prices. They concluded that: oil prices can be used for estimating gold prices or vice versa, at least in the analysis period (2 January 1995–3 June 2009).

Wang and Chueh (2013) dealt with the short-term and long-term dynamic interactions among interest rates, oil prices, gold prices and the U.S. dollar. The study employed the cointegration model and the error correction model for analysis covering the period between 2 January 1989 and 20 December 2007. It was seen that gold prices and crude oil prices were related positively in the short term.

Le and Chang (2012) collected data from May 1994 to April 2011 to test the effect of oil price on gold market by using vector autoregressive approach. The results performed that the appearance of oil price shocks had a significant and positive influence on real gold markets. These findings implied that the changes of oil price fluctuations can use to estimate the movements of gold price. Zhanga and Wei (2010) observed the data from 2000 to 2008 and they found that the significant coefficient which represents for the relation between the gold price and the crude oil price was 0.9295.

In another article, the authors (Baig, Shahbaz, Imran and Jabbar, 2013) examine, whether there is a long-term relationship between KSE100, gold and oil prices. KSE 100 Index was used for the analysis, which is a measure to compare prices on the Karachi Stock Exchange. The authors suggest that there is no long-term relationship between gold prices and stock market returns. Furthermore, the study argues that stock market returns are not affected by gold prices or oil prices.

In further studies, the authors explore the relationship between these commodities and other macro-economic factors. Cashin (1999) tested the dependence of seven commodities in the period from April 1960 to November 1985. The empirical results of this study show that there is a significant relationship between oil prices and gold prices.

2 Characteristics of the commodities

2.1 Characteristics and price developments of oil

The main characteristics of oil as an investment instrument are high liquidity, relatively high volatility and the possibility of profit. Classification of types of oil is based on fractional and chemical composition. The basic unit of measurement is one barrel of oil (about 159 litres). Extracted oil is compared with the regional standard (benchmark crude oil), which is used to determine the price. The standard used in the

United States is called West Texas Intermediate - WTI, standard for the North Sea is called Brent and standard for the Middle East is called Dubai. An important factor influencing the oil market is price, which is determined by global supply and demand.

The demand is not flexible in the short term, as there is no substitute, which would fully replace oil as a source of fuel and energy. In the long run, when considering alternatives of this commodity, the demand is more flexible. Main factors influencing the demand include: the world's population, development of the world's GDP, structural changes in the economy, changes in energy balances, climate conditions and their changes, exchange rates of importers against the US dollar, trade and political measures of importing countries, speculative and other influences. This was reported by (Baláž, 2000).

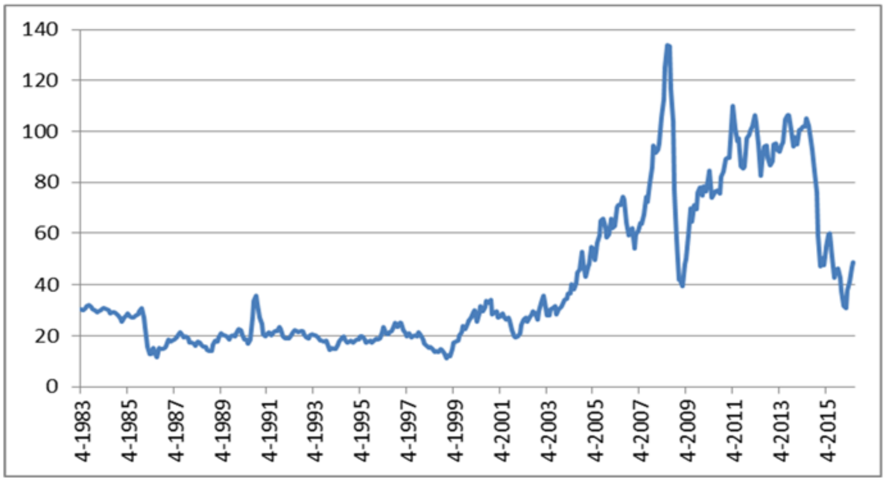
Oil supply is inflexible in the short term, mainly due to costs associated with the production of oil. Nevertheless, like oil demand, oil supply is also flexible in the long term. Investments in the oil industry and the size of the supply depend on the following factors: the size of proven global oil reserves and discoveries of new deposits, technical and technological advances in extraction and processing of oil, monetary systems in producer countries, political factors, activities of OPEC and NOPEC (Non-oil Power Exporting Countries), short-term factors: natural disasters, accidents, political and military conflicts. This was reported by (Baláž, 2000).

In the long term, the supply is determined by the size of investments in the oil processing industry. The countries of OPEC regulate oil prices by increasing or decreasing their production. In the short term there are significant fluctuations, e.g. during hurricanes and earthquakes.

There are about 30 thousand oil deposits in the world. Nearly 85% of the world reserves are stored in about 0.5% of oil deposits, as stated by (Leroen, 2002). The largest oil deposits are located in the territories of Saudi Arabia, Iraq, Iran, Kuwait and the United States. Diesel fuel experts say that the majority of technologies for oil production are already here. The technologies can be improved, but one cannot expect any major technological advance in this area.

Development of prices of this commodity from April 1983 to December 2016 is shown on the Fig. 1.

Fig. 1: Development of oil prices (in USD/Barel, April 1983 – December 2016)



Source: U.S. Energy Information Administration.

2.2 Characteristics and price development of gold

Gold is a safe means of payment, which maintains its value. Gold is a precious metal, which is used in jewellery, electronics, and numismatics. The classical unit of measurement used for gold is troy ounce, and the following applies: 1 troy ounce = 31.1034807 grams; 32.15 troy ounces = 1 kg. Besides weight, purity of gold is also measured.

Supply and demand is the main factor, which determines the price of gold. Like in the case of oil, gold demand is not flexible in the short term, because there is no substitute for fully replacing gold as a commodity with specific properties. In the long run, the demand is flexible. Factors, which affect the overall gold demand, include: world population, development of the world GDP, growth in living standards, economic and political situation, policy of central banks, currency exchange rates relative to the USD, technological development, speculation and other factors.

Gold supply is not flexible in the short term, mainly due to the nature of mining. Gold demand is flexible in the long term. Main factors, which affect the supply of this commodity, include: the amount of global gold reserves, recycled gold and discoveries of new deposits, technical and technological advances in gold mining, monetary system in each country, political factors, short-term factors: natural disasters, political and military conflicts.

Gold mining companies, which are mining gold on all continents, contribute to oil supply. At present, the overall level of gold production is stable. The stability of the production results from the fact that the discovered mines mostly serve for compensation of the current production and not for expansion of the global supply. Gold mining takes relatively long time, and therefore supply of gold is relatively inflexible. Gold supply is not able to respond to changing price developments in the short time. Central banks and international organizations hold almost a fifth of the world's mined gold reserves in the form of reserve assets. Each government holds an average 10% of their reserves in gold. Sale of gold is also affected by CBGA (Central Bank Gold Agreement), the aim of which is to stabilize the gold market. Price development of this commodity from April 1983 to December 2016 is shown on the Fig. 2.

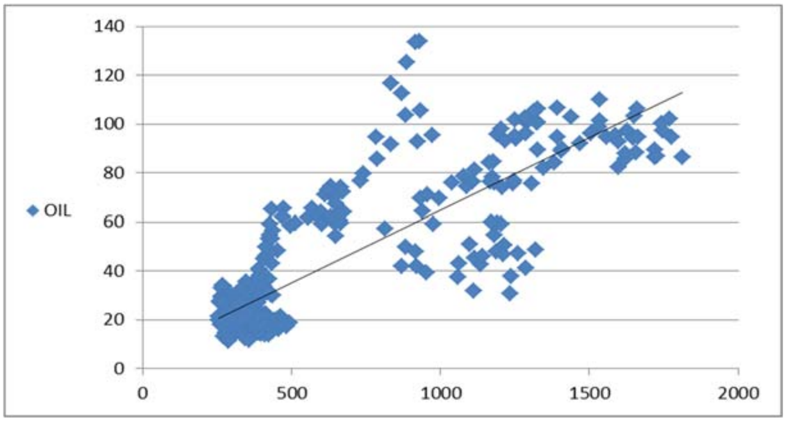
Fig. 2: Development of gold prices (in USD/troy ounce, April 1983 –December 2016)

Source: World Gold Council

3 Analysis of the relationship between gold and oil prices

Monthly data from April 1983 to December 2016 were used to test the relationship of gold and oil. WTI crude oil price in dollars per barrel is shown as the representative of the oil market. The data are from the portal U.S. Energy Information Administration. The gold price is given in dollars per troy ounce. The data are from the World Gold Council website. Each time series includes 405 observations. Prices of these commodities have been evolving roughly in the same manner, as one can visually assess from the point chart on the Fig. 3.

Fig. 3: GOLD vs. OIL



Source: own calculations

The ratio of the gold price per troy ounce to the crude oil price per barrel is referred to as the indicator GOR. The ratio of gold to oil allows for quantification of the relationship of prices of gold and oil.

If the ratio of gold to oil is high, it means that gold is overvalued in relation to oil, so either gold is too expensive or oil is too cheap. The Tab. 1 presents descriptive statistics for the variable GOR. The mean value between the two commodities is 16.17; the standard deviation has the value of 5.76. After fluctuations, GOR values approach the average, as markets resist fluctuations, and since when the price of oil increases, the price of gold will rise as well and the value of GOR returns to the average value.

Tab. 1: Descriptive statistics GOR

	GOR
Mean	16.17
Minimum	6.67
Maximum	40.33
Std.Deviation	5.76

Source: program GRETL, own calculations

The value of the correlation coefficient 0.841 indicates that there is a high level of dependency between prices of oil and gold. The coefficient is statistically significant at the significance level of 0.05. However, a high value of the correlation coefficient does not yet confirm the existence of a causal relationship. The values of correlation coefficients in a shorter period are very interesting, as shown in the Tab. 2.

Tab. 2: The value of correlation coefficient in time

Period	The value of coefficient	Significance
4/1983 – 12/1987	-0.249	0.061
1/1988 – 12/1992	-0.251	0.052
1/1993 – 12/1997	-0.213	0.102
1/1998 – 12/2002	-0.061	0.647
1/2003 – 12/2007	0.895	0.000***
1/2008 – 12/2012	0.288	0.025**
1/2013 – 12/2016	0.567	0.000***

***statistical significance at the 0.01 level, ** statistical significance at the 0.05 level

Source: program GRETL, own calculations

In some periods, the correlation coefficient even becomes a negative value, so prices of gold and oil may evolve in the opposite directions, but these values are not statistically significant at the significance level of 0.05. There are values from the first four periods in the Tab. 2. The values are statistically significant only since 2003, which may be due to the fact that the development of one commodity slowed down, but did not develop in the opposite direction in the previous years, when the correlation coefficient was negative.

However, the correlation coefficient does not give information on the causal relationships between the examined commodities. Granger-causality is tested in the following text. This means that there is a correlation between the current value of one variable and past value of other variables.

3.1 Granger causality

Using linear regression, we study the relationship of a random independent variable x (oil price) and the dependent variable y (gold price). It is verified, whether time series are stationary, so that regression analysis could be used. Stationarity of time series was tested using the extended Dickey-Fuller test (ADF test), which rejects or does not reject the null hypothesis about the existence of a unit root, the so-called non-stationarity of a time series, as reported in the literature by (Hamilton, 1994) and (Černý, 2015).

Before performing the analysis, logarithms were taken with regard to both time series (LNOIL, LNGOLD). The logarithmic transformation is used to reduce heteroskedasticity and skewness. The Tab. 3 shows the results of testing stationarity using the Augmented Dickey Fuller test (ADF test). The variables LNOIL and LNGOLD for VAR model exhibit the properties of first-order non-stationarity, i.e. I(1); therefore, the long-run cointegration relationships may exist between these variables.

Tab. 3: Augmented Dickey-Fuller test

Data	Test Statistics	Critical Value (α =0.05)	Result
LNOIL	-1.64	-2.89	Nonstationary TS
LNGOLD	- 0.97	-2.89	Nonstationary TS
D(LNOIL)	-6.15	-2.89	Stationary TS
D(LNGOLD)	-3.29	-2.89	Stationary TS

Source: program GRETL, own calculations

Changes in LNOIL Granger cause changes in LNGOLD with 1 month delay. This is a short-term causal relationship. Granger causality was not demonstrated in any direction in case of other delays, as shown in the Tab. 4.

Tab. 4: Testing Granger causality

	Significance					
Delay	1	2	3	4	5	6
D(LNOIL)→D(LNGOLD)	0.04**	0.13	0.21	0.33	0.41	0.49
D(LNGOLD)→D(LNOIL)	0.79	0.65	0.71	0.75	0.86	0.88

** statistical significance at the 0.05 level

Source: program GRETL, own calculations

4 Testing the long-term relationship

This part of the article deals with the cointegration test and elaboration of the model, which will be used to analyse the long-term relationship between oil and gold prices.

Stationarity of the time series was investigated previously (Tab. 3). Null hypothesis (H_0: there is a unit root) were not rejected, indicating the presence of a unit root in both time series, therefore non-stationarity, which is a prerequisite for the cointegration test, as indicated by (Arlt, 1999) and (Artl, 2006). Stationarity was observed after the first difference, as shown in the Tab. 3.

It is also necessary to determine the order of delay of the vector autoregression (VAR) model. For example, (Ivanov and Kilian, 2005) propose using three criteria for this purpose, namely the Bayesian Information Criterion (BIC), Hannan-Quinn Information Criterion (HQN) and Akaike Information Criterion (AIC). The results in the Tab. 5 show that the optimum time of delay is one month.

Tab. 5: The order of delay

Delay	**AIC**	**BIC**	**HQN**
1	-5.524036*	-5.461080*	-5.499039*
2	-5.514790	-5.409863	-5.473129
3	-5.496508	-5.349611	-5.438184

* indicates the best (ie minimized) the value of the information criterion

Source: program GRETL, own calculations

To determine, whether there is a long-term relationship between variables, the cointegration tests is used, namely the Johansen test. The results of the test criterion are shown in Tab. 6.

Tab. 6: Johansen cointegration test

H_0: The number of cointegration vectors	**Track test**	**Significance**
0	15.72	0.0043***
1	0.41	0.8145

*** statistical significance at the 0.01 level

Source: program GRETL, own calculations

The Tab. 6 shows that the system contains one cointegration relationship in the period under review, demonstrating cointegration between the prices of gold and oil.

The Vector Error Correction Model (VECM) enables us to capture both long and short-term relationships between variables. The resulting VECM model was estimated with the order of delay 2. The order of delay is selected as greater by one than the delay of the VAR model in the Tab. 5.

In the first model, we test whether the change in oil prices is the cause of the change in gold prices. Results of the VEC model can be found in the Tab. 7.

Tab. 7: Model results

	Coefficient	**Std.error**	**t-ratio**	**Significance**
Constant	0.019	0.011	1.672	0.09519
D(LNGOLD(-1))	-0.122	0.050	-2.429	0.01555**
D(LNOIL(-1))	0.008	0.026	0.308	0.75801
EC1	-0.007	0.005	-1.431	0.15323

** statistical significance at the 0.05 level *Source: program GRETL, own calculations*

$$D(LNGOLD_t) =$$
$$= 0.019 - 0.122 \cdot D(LNGOLD_{t-1}) + 0.008 \cdot D(LNOIL_{t-1}) - 0.007 \cdot rez_{t-1} + \varepsilon_t \quad (1)$$

The value of EC1 coefficient is not statistically significant, so changes in oil prices will not cause changes in gold prices in the long term.

In the second model, we test whether the change in oil prices is the cause of the change in gold prices. Results of the VEC model can be found in the Tab. 8.

Tab. 8: Model results

	Coefficient	**Std.error**	**t-ratio**	**Significance**
Constatnt	-0.055	0.021	-2.673	0.00781***
D(LNGOLD(-1))	0.120	0.054	2.216	0.042448**
D(LNOIL(-1))	0.323	0.048	6.706	0.00001***
EC1	0.026	0.009	2.755	0.00613***

***statistical significance at the 0.01 level, ** statistical significance at the 0.05 level

Source: program GRETL, own calculations

$$D(LNOIL_t) =$$
$$= -0.055 + 0.12 \cdot D(LNGOLD_{t-1}) + 0.323 \cdot D(LNOIL_{t-1}) + 0.026 \cdot rez_{t-1} + \varepsilon_t \quad (2)$$

Causality is captured by the statistically significant value EC1 (0.026), which indicates that this variable will be modified by 2.6% within 1 month in case of long-term instability of the price level of oil. In other words, complete elimination of instability would last approximately 38 months (1/0.026).

Regarding the statistical significance of regression coefficients in the equation (2), we find out that the price of oil is positively related to the price of gold - with a delay of one month, meaning that a growth of gold prices is followed by a growth of oil prices within one month. And of course, the oil price in a given month is related to the oil price in the previous month.

The Tab. 9 shows testing results of the assumptions of the model. Doornik - Hansen test is applied in order to test normality with the result of rejecting the null hypothesis. However, (Johansen, 1995) states that the assumption of normality is not essential for stability of the model. Ljung - Box test does not reject the null hypothesis of absence of autocorrelation. ARCH - LM test does not reject the null hypothesis of absence of heteroscedasticity. The tests were performed at the significance level of 0.05.

Tab. 9: The assumptions of the model

	Autocorrelation	**Heteroscedasticity**	**Normality**
Null hypothesis	H_0: absence of	H_0: absence of	H_0: normality of
Test	Ljung – Box	ARCH – LM	Doornik – Hansen
Significance	0.848	0.062	0.000***

***statistical significance at the 0.01 level

Source: program GRETL, own calculations

Conclusion

This paper examined two commodities: gold and oil. The aim was to determine the degree and nature of the relationship between the price levels in terms of short- and long-term relationships. First, a correlation analysis was performed. A strong correlation was confirmed between the commodities, while the correlation coefficient acquired even negative values after division into shorter time intervals, but these values were not statistically significant.

The gold to oil ratio analysis shows that the value of the average ratio is 16.17. If the ratio is higher, then gold is overvalued in relation to oil (gold is too expensive or oil is too cheap). The ratio is increasing during economic growth, the ratio is low in case of deceleration of economic activity.

Based on Granger causality testing, it was found out that a change in oil prices precedes the development of gold prices by one month. Causality was not demonstrated in the opposite direction.

The oil and gold markets are moving on the same foundations and these two commodities are important for any economy. These markets are influenced by government policy and not just by supply and demand. An important role is also played by globalization, as most markets are not isolated, but interrelated. Johansen cointegration test results confirmed the existence of cointegration relationship, and the assumption of existence of a long-term relationship between the analysed commodities was also confirmed. The used Vector Error Correction model allows for detecting of both long and short-term relationships between the examined variables. The resulting model (2) showed that there is a positive relationship between the price of oil and the price of gold – with delay of one month, meaning that a growth of gold prices is followed by a growth of oil prices within one month. Regarding the diagnostic of the model (2), then the performed tests, which found out the presence of autocorrelation or heteroscedasticity, and also the normality test demonstrate stability of the model.

Most studies, such as Narayan, Narayan, and Zheng (2010), Wang and Chueh (2013), Le and Chang (2012), Zhanga and Wei (2010), addressing this issue state that the relationship between gold and oil exists. The relationship was investigated in both short-run and long-run. In the long-time relationship, the authors found emphasized that gold prices were more sensitive to rising oil prices. And it is consistent with the results of this article.

The results achieved correspond with the study of Mielcová (2009) who states that one co-integration relationship was confirmed, which argues that changes in the price of gold affect future changes in the price of oil. Conversely, Radomský (2012) argues that gold and oil price levels are indeed strongly correlated, but only in the short term. It is not the case within a long-term analysis.

Both commodities have an important role in determining prices on the commodities market, and therefore it is important to analyse their relationship. Results of the article may be useful for further analysis, which should investigate other macroeconomic factors affecting the mutual development of gold and oil prices, as suggested in their studies by the authors Baig, Shahbaz, Imran and Jabbar (2013) and Cashin (1999).

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References

Arlt, T. (1999). *Moderní metody modelování ekonomických časových řad.* Praha: Grada. ISBN 80-7169-539-4.

Arlt, T., Arltová, M. (2006). *Ekonomické časové řady.* Praha: Grada. ISBN 978-80-247-1319-9.

Baig, M. at al. (2013). *Long Run Relationship between Gold Prices, Oil Prices and Karachi Stock Market*. Acta Universitatis Danubius. Economica, Vol 9, No 5.

Baláž, P. (2000). *Ropa a svetové hospodárstvo v období globalizácie.* Bratislava: Sprint. ISBN 80-88848-85-7.

Blake, N., Fomby, T. (1997). *Theshold cointegration.* New York: R.Springer. ISBN 952-5299-79-1.

Cashin, P. (1999). *Booms and slumps in world commodity prices*. Reserve Bank of New Zealand Discussion Paper vol. 99 (8)

Černý, A., Kočenda, E. (2015). *Element of time series econometrics: an applied approach.* Prague: Charles University in Prague, Karolinum Press. ISBN 978-80-246-3199-8.

Enders, W. (1998). *Unit-Root Tests and Asymmetric Adjustment With an Example Using the Term Structure of Interest Rates.* In: C.W.J. GRANGER, ed. Journal of Business and Economic Statistics 16, 304 – 11.

Enders, W. (2001). *Cointegration and Threshold Adjustment*. In: P. SIKLOS, ed. Journal of Business & Economic Statistics, vol. 19, issue 2, pages 166-176.

Hamilton, J. (1994). *Time Series Analysis.* Princeton: Princeton Univ.Press. ISBN 0-691-04289-6.

Hančlová, J., Tvrdý, L. (2003). *Úvod do analýzy časových řad.* Ostrava: Ekonomická fakulta VŠB-TU Ostrava.

Ivanov, V. (2005). A Practitioner´s Guide to Lag-Order Selection for VAR Impulse Respone Analysis. In: L. KILIAN, ed. *Studies in Nonlinear Dynamics and Econometrics.*vol 9, no. 1, pp. 1219-1253.

Johansen, S. (1991). *Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models*. Econometrica, Vol. 59, No. 6, s. 1551-1580. Available at: http://www.jstor.org/stable/2938278.

Johansen, S. (1995). *Likelihood-based Inference in Cointegrated Vector Autoregressive Models.* Oxford: Oxford University Press. ISBN 9780198774501.

Le, H., Chang,Y. (2012). Oil price shocks and gold returns. *International Economics*.Vol.131, 71-103.

Leroen, B. V. (2002). *Drops of black gold.* Stavanger: Statoil. ISBN 82-991255-5-3.

Mielcová, E. (2009). Co-Integration in the Oil and Gold Prices. *Acta Academica Karviniensia.* Karviná: OPF SU, s.265-271. ISSN 1212-415X.

Narayan, P. K., Narayan, S., and Zheng, X. (2010). Gold and oil futures markets: Are markets efficient? *Applied Energy*, 87, 3299–3303.

Radomski, P. (2012). Where the Relationship between Gold and Oil Works and Where It Does Not. [Accessed. 9. 2. 2017]. Available at: http://www.sunshineprofits.com/gold-silver/free-alerts/where-relationship-between-gold-and-oil-works-and-where-it-does-not/

U.S. Energy Information Administration. [Accessed 20.1.2017]. Available at: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rclc1&f=m

Wang, Y., Chueh, Y. (2013). Dynamic transmission effects between the interest rate, the US dollar, and gold and crude oil prices. *Economic Modelling*, 30, 792–798.

World Gold Council. [Accessed 20.1.2017]. Available at: http://www.gold.org/statistics#group1

Zhanga, J., Wei., M. (2010). The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. *Resources Policy* Vol.35, 168-177.

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