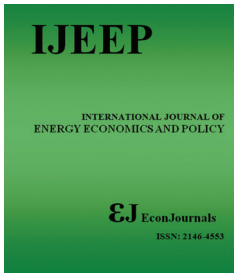

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Interdependence between WTI Crude Oil Prices and the US Equity Market

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ABSTRACT

The author checks the cointegration between WTI oil market and the US market of stocks represented by the S&P index. As it turns out not to exist, short-term relations are investigated. The study confirms that crude oil market significantly influences the stock market in the short run, however it does not give an unambiguous answer if this impact is made by oil itself or together with the GBP/USD currency rate. Furthermore, the relation does not go in another direction which means that the stock market has no impact on the oil market. The Unrestricted Vector Autoregression model is built. The author uses weekly data and the research period is from April 1990 to May 2021. The study implies that stable crude oil prices are desirable in order not to destabilize stock markets whose instability threatens the real economy. Conclusions are vital for a wide group of entities such as policy makers, authorities, institutional and individual investors, as well as other financial market participants.

Keywords: Unrestricted VAR, Equity, Crude oil prices, Cointegration
JEL Classifications: C51, F37, G15

1. INTRODUCTION

Relations between crude oil prices and stock markets have been a subject of many scientific papers for years (Arouri and Nguyen, 2012; Degiannakis et al., 2013; Youssef and Mokni, 2019; Hwang and Kim, 2021) and so far, there has been no single theory explaining them. There exist both theories confirming it and denying it. At the same time, the behavior of stock markets influences other markets and the economy (Levine and Zervos, 1996; Durusu-Ciftci et al., 2017; Guru and Yadav, 2019), so it is important to get to know what factors impact them.

The aim of the paper is to verify relations between crude oil prices and the equity market with an example of the United States which is claimed to be the global economy which influences other countries development (Kose et al., 2017). Thus, conclusions are globally valid which is the paper advantage. Another strong side of the study is a very long period of time covering more than 30 years and considering various economic situations such as different crises or even the Covid-19 one.

The research question is the following: are crude oil prices related to stock market prices. If so, what is the direction of this influence and is it a long-term or short-term relation? The literature does not give clear answers to these questions, so there is a need for doing the research in this field. The answer to the research question shows that crude oil influences the stock market, however it is not obvious if it does it by itself only or together with the currency market represented by GBP/USD. Moreover, the relation does not go in another direction which means that the stock market has no impact on the oil market. The study implies that stable crude oil prices are desirable in order not to destabilize stock markets whose instability threatens the real economy. Conclusions are important for a wide group of entities such as policy makers, institutional and individual investors, authorities or other financial market participants.

2. REVIEW OF THE LITERATURE

Although more and more often we can here about the green revolution (Niedziółka, 2021), crude oil is still one of the most important energy assets. The literature does not give a standardized view on the relation between crude oil prices and equity prices. Conclusions are often contrary and depend on the country analyzed, period of time and its lengths, methodology, the choice of markets for the research. The existing research is not transparent as there are papers in which authors prove that there exists either short – term or long – term relation between crude oil prices and the equity market. However, some of them claim the positive, some others the negative influence. They also differ with directions of this influence. Sometimes they state that it has been changing in time or its strengths depends on the sector. We can also find totally different conclusions suggesting that such a relation does not exist at all.

Among papers which show the relation between the crude oil and the equity market in different countries we can find (Alamgir and Amin, 2021) who examine the dependence between oil prices and stock markets in South Asia. They construct a panel ARDL model and conclude that there is a positive relationship between oil prices and stock indexes (Arouri et al., 2011) check the relation between oil prices and stocks from different sectors and find out that the former positively influence the latter. Authors notice that stock prices are impacted by oil prices not only because of changes of the marginal production cost, but also because of the influence of oil prices on economic growth or products demand. Also Kumar et al., 2020 summarize that there is a positive impact of oil on the stock market after having examined interdependencies between crude oil, stock market, gold and exchange rate in India. Contrary, Arfaoui and Rejeb, 2017 check links between oil prices, gold, stock market and US dollar showing that there is a negative relation between oil and stocks. Asteriou and Bashmakova, 2013 check the link between crude oil prices and stock market behavior for CEE countries in 1999–2007. They also notice that the stock market reacts negatively to changes of oil prices and the effect is stronger for lower levels of oil prices. Arouri and Rault, 2012 examine long-run interconnections between oil prices and stock markets in GCC countries and find cointegration between these variables. Arouri and Rault, 2010 analyze the linkage between oil prices and stock markets in GCC countries of South Arabia. They show that there is a bidirectional nexus between these two variables. Degiannakis et al., 2014 check the influence of conditional, market and implied volatility on the stock market in Europe. Authors summarize that oil price fluctuations influence the volatility of the stock market. What's more, the influence is noticeable both for present and future volatilities. Shabbir et al., 2020 check relations between gold, oil and stock market in Pakistan in 1991–2016. They use the ARDL model and conclude that there is a strong impact of oil on the equity market. Coronado et al., 2018 verify relations between gold, oil and stock markets in the United States in 1986 - 2017. They state that the influence goes in two directions, which means that it is both oil market which impacts the stock market and the stock market which influences the oil market. Zhu et al., 2021 question about interrelations between oil shocks and the stock market and confirm them. Hwang and Kim, 2021 apply the nonlinear vector autoregression model and prove that the US stock market responds to shocks of oil prices.

Stressing the role of sectors in examinations on the linkage between oil and equity market (Arouri and Nguyen, 2012) prove the short – term influence of oil on European stock markets, however they stress that the overall effect depends on the sector. Awartani and Maghyereh, 2013 emphasize that transmissions of both return and volatility between oil and Gulf Cooperation Countries are in both directions. Arouri et al., 2012 use VAR-GARCH approach to show the transmission of volatilities between oil and stock markets in Europe exists both for single sectors and aggregate. Degiannakis et al., 2018 pay attention to the methodology of different studies and find out that results of the research on the relation between oil and equity markets often depend on the fact if the equity market is somehow related to the oil sector for example by operating in the oil exporting or importing country.

As for papers paying attention to fluctuations of the relation between the crude oil market and the equity market, there is one prepared by (Youssef and Mokni, 2019) which verifies the dynamic relationship between crude oil and stock markets of oil-exporters and oil-importers. Authors use DCC-FIGARCH model in 2000–2018 to find out that this linkage exists but varies in time. Degiannakis et al., 2013 check the correlation between crude oil prices and European stock market understood as industrial indices. Authors show that the correlation varies in time and that it depends on the industry sector. Reasons for correlation between equity and oil markets can be divided into two groups. In the first one there can be named fundamental factors. In the second group of studies authors emphasize the role of speculants such as for example hedge funds or investment banks. Silvennoinen and Thorp, 2013 explain that this is because of such investors that commodities markets and stock markets are more and more correlated. They construct the DSTCC_GARCH model to show the rising correlation between these markets. It is also the paper prepared by Buyuksahin and Robe, 2011 where they confirmed the influence of trader positions on prices of energy commodities and prove that because of speculant activities the relation between equity and investable energy markets is stronger and stronger in time. Furthermore, Sadorsky, 2014 investigates correlation between emerging markets stocks and oil to conclude that it has been rising since 2008.

Among papers which deny the relation between crude oil and stock prices we can enumerate (Apergis and Miller, 2009) who broadly examine the impact of structural shocks coming from the oil market on stock markets of a few countries including United States, United Kingdom, Japan, Italy, Germany, France, Canada and Australia. Authors engage a vector error correction and vector autoregressive model to summarize that stock markets do not react to oil prices. Yadav et al., 2021 can also be mentioned here as they prove no long – term relation after having examined the linkage between oil and the Indian equity market reflected by the Sensex index. After having denied cointegration between examined variables authors build a VAR model to show the short-term causality between oil and stock market.

All in all, although there exists plenty of research on the subject, there is no unity on the relation between the oil market and the equity quotations. Besides, many papers suggest that this linkage has been changing during the time, which justifies extending the research on it for further and longer periods of time.

3. METHODOLOGY, DESCRIPTIVE STATISTICS AND PRE-RESEARCH TESTS

Weekly prices of spot WTI crude oil prices and the S&P500 index are applied. They were downloaded from the publicly available source www.investing.com. The study period is from April 1990 to May 2021. GBP/USD is used as a control variable. The reason for choosing it was that it is widely known that the currency market influences both stock and oil market. Furthermore, other checked main currency pairs did not fulfill assumptions of the model constructed in the study.

In the first step charts of examined variables are analyzed (Charts 1-3) and the main statistics are calculated. It lets confirm the significant correlation between examined variables (Table 1).

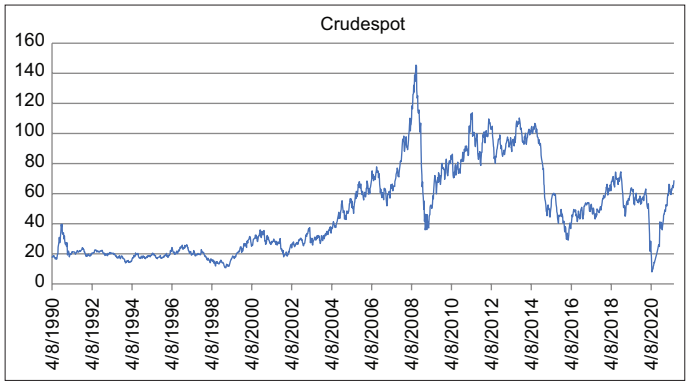
The S&P500 index is significantly correlated with crude oil WTI spot prices, although the Pearson linear correlation coefficient is rather low (0.17 with P = 0.0000) and it does not say anything about the direction of examined relations. The correlation between GBP/USD and the S&P500 index is significant and equals to almost 0.16 (p = 0.0000). Significant correlation coefficient between USDGBP and crude oil is also low (about 0.12 with p = 0.0000).

Table 1: Correlation coefficients between examined variables

	lnSP500	lnGBPUSD	lnCrudespot
lnSP500	1	0.1596 (P=0.0000)	0.1706 (P=0.0000)
lnGBPUSD	0.1596 (P=0.0000)	1	0.1203 (P=0.0000)
lnCrudespot	0.1706 (P=0.0000)	0.1203 (P=0.0000)	1

Source: Author's calculations

Chart 1: Spot prices of WTI crude oil between April 1990 and May 2021

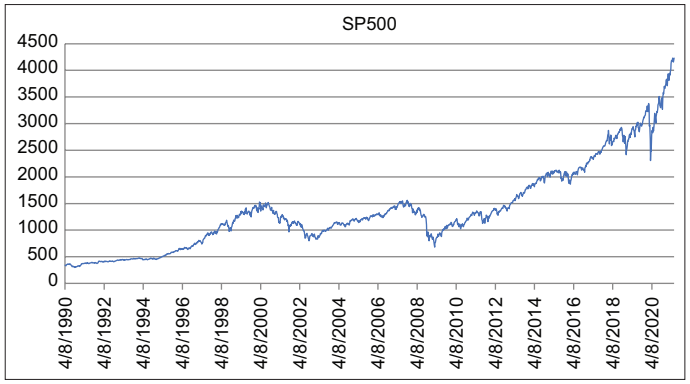


Source: Author's own study based on the data from www.investopedia.com, accessed: May 30, 2021

Table 2 depicts other statistics. As far as standard deviation (also variance) is concerned, it is the highest for crude oil (0.0571846 for standard deviation and 0.0032701 for variance) and the lowest for GBP/USD currency rate (0.0133276 and 0.0001776 respectively). Such results show that crude oil market is more volatile than the stock market reflected by the S&P500 index. Risk measured with skewness is also the highest for crude oil (–1.953965) and the lowest for the currency market (–0.6364347). The same conclusions can be drawn from kurtosis which is equal to 35.62878 for the oil market and 7.228537 for the currency market. To sum up, all presented risk measures give the same results saying that the crude oil market is connected to higher risk levels than the stock market. The average logarithmic rate of return (mean) is the lowest for the GBP/USD currency rate (–0.0000899). The second place belongs to crude oil with the rate of 0.0008305 whereas the highest average rate of return is achieved by S&P500 (0.0015436).

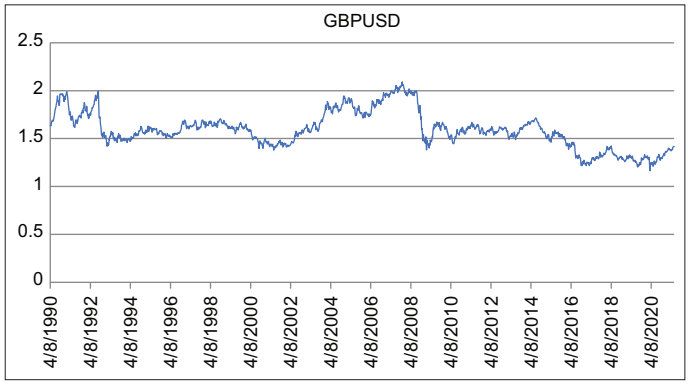
Before trying to fit the correct model, stationarity tests were conducted. Augmented Dicker-Fuller test was used (Dickey and Fuller, 1979; Harris, 1982). Results gathered in Tables 3 and 4 show that all variables are non-stationary in I(0) (P = 0.3615 for crude oil, P = 0.2258 for USD/GBP currency rate and P = 0.9986 for S&P500) and stationary in I(I) (P = 0.0000 for crude oil, P = 0.0000 for USD/GBP currency rate and P = 0.0000

Chart 2: Values of the S&P500 index between April 1990 and May 2021



Source: Author's own study based on the data from www.investopedia.com, accessed: May 30, 2021

Chart 3: GBP/USD currency rates between April 1990 and May 2021



Source: Author's own study based on the data from www.investopedia.com, accessed: May 30, 2021

Table 2: Descriptive statistics of examined data

Variable	Min	Max	Mean	Standard deviation	Variance	Skewness	Kurtosis
lnSP500	–0.2008375	0.1142367	0.0015436	0.0233717	0.0005462	–0.8678178	10.68131
lnGBPUSD	–0.1015782	0.0675776	–0.0000899	0.0133276	0.0001776	–0.6364347	7.228537
lnCrudespot	–0.8210306	0.5041312	0.0008305	0.0571846	0.0032701	–1.953965	35.62878

Source: Author's calculations

for S&P500). First differences were calculated as differences of natural logarithms (logarithmic rates of returns).

The optimum number of lags for the searched model was established with such criteria as Akaike's Final Prediction Error abbreviated to FPE (Akaike, 1969; 1970; 1971) and Akaike Information Criterion abbreviated to AIC (Akaike, 1973; 1974). Both of them show that it is 2 (Table 5).

In Tables 6 and 7 results of cointegration tests are presented. It was checked by Johansen cointegration test (Johansen, 1988) which is very often applied for checking if long – term relations exist (Haialmarsson and Oesterholm, 2007;Gao et al., 2018; Bhuvaneshwari and Ramya, 2017; Silva et al., 2014). The condition for using it is that variables are non-stationary at level and stationary at first differences. It is fulfilled. Trace statistic and max statistic confirm that there exist at least zero cointegration equation which can be interpreted that there is no long – term relation between S&P500 index and the crude oil market. There is only a possibility of a short – term relation is which will be modelled by an unrestricted VAR model in the next part of the paper.

4. UNRESTRICTED VECTOR AUTOREGRESSION MODEL AND RESEARCH RESULTS

Unrestricted vector autoregression model can be built when the following three conditions are fulfilled:

- Time series used to build a model are non-stationary at level
- Time series are stationary at first differences
- There cannot be a cointegration between variables.

All of them are executed in this case which was justified in the earlier part of the paper, so the VAR model seems to be the good one to reflect relations between crude oil prices and the American stock market. As it was analyzed earlier, the optimum number of lags for the VAR model is 2. Thus, the constructed model is the following:

$$CRUDESPOT = \alpha_0+\alpha_1 CRUDESPOT\ (L1)+\alpha_2 CRUDESPOT\ (L2)+\alpha_3 USDGBP\ (L1)+\alpha_4\ USDGBP\ (L2)+\alpha_5 S\&P500\ (L1)+\alpha_6 S\&P500\ (L2)+\xi_{1t} \quad (1)$$

$$USDGBP = \alpha_7+\alpha_8 CRUDESPOT\ (L1)+\alpha_9 CRUDESPOT\ (L2)+\alpha_{10} USDGBP\ (L1)+\alpha_{11}\ USDGBP\ (L2)+\alpha_{12}\ S\&P500\ (L1)+\alpha_{13}\ S\&P500\ (L2)+\xi_{3t} \quad (2)$$

$$S\&P500 = \alpha_{14}+\alpha_{15} CRUDESPOT\ (L1)+\alpha_{16} CRUDESPOT\ (L2)+\alpha_{17} USDGBP\ (L1)+\alpha_{18}\ USDGBP\ (L2)+\alpha_{19}\ S\&P500\ (L1)+\alpha_{20}\ S\&P500\ (L2)+\ \xi_{4t} \quad (3)$$

Table 3: Results of stationarity tests of examined series in I (0)

Variable in I (0)	Results of ADF tests
Crude oil spot price	Non-stationary (P=0.3615)
USD/GBP currency rate	Non-stationary (P=0.2258)
S&P500	Non-stationary (P=0.9986)

Source: Author's calculations

Table 4: Results of stationarity tests for examined series in I (1)

Variable in I (1)	Results of ADF tests
lnCrude oil spot price	Stationary (P=0.0000)
lnUSD/GBP currency rate	Stationary (P=0.0000)
lnS&P500	Stationary (P=0.0000)

Source: Author's calculations

Table 5: Results of tests for the maximum number of lags

Number of lags	p	FPE	AIC
0	-	1.0e+07	24.6437
1	0.000	3.69395	9.82033
2	0.001	**3.6695**	**9.81369**
3	0.047	3.67154	9.81424
4	0.035	3.67151	9.81423

Source: Author's calculations

Table 6: Results of Johansen tests for cointegration (trace statistic)

Maximum rank	Prms	LL	Eigenvalue	Trace statistic	Critical value
0	21	–7944.02	-	20.2489*	29.68
1	26	–7939.16	0.00597	10.5337	15.41
2	29	–7935.31	0.00474	2.8296	3.76

Source: Author's calculations

Table 7: Results of Johansen tests for cointegration (max statistic)

Maximum rank	Prms	LL	Eigenvalue	Max statistic	Critical value
0	21	–7944.02	-	9.7152	20.97
1	26	–7939.16	0.00597	7.7041	14.07
2	29	–7935.31	0.00474	2.8296	3.76

Source: Author's calculations

where:

α_0, α_1… α_{20} – structural parameters of the assessed model

ξ_{1t}…ξ_{3t} – random errors of estimation

- CRUDESPOT (L1) – first lag of the crude oil WTI spot price
- CRUDESPOT (L2) – second lag of the crude oil spot price
- S&P500 (L1) – first lag of the S&P500 index value

- S&P500 (L2) – second lag of the S&P500 index value
- USDGBP (L1) – first lag of the USD/GBP currency rate
- USDGBP (L2) – second lag of the USD/GBP currency rate.

As data gathered in Table 8, crude oil influences the S&P500 index in lag 2 with P = 0.041, however the S&P500 index does not impact the crude oil market (P = 0.979 for lag1 and P = 0.512 for lag2). These are similar results as for Granger causality test, although the difference is that the influence of oil on the stock market is done together with the currency market (GBP/USD).

Table 9 shows results of Wald tests for Granger causality. The data show that the oil market together with the currency market represented by GBP/USD currency rate influence crude oil prices with P = 0.049, however the S&P500 index does not influence the oil market (P = 0.806). Thus, the relation between these two markets goes in only one direction and is short-term.

To check the goodness of the model, it is necessary to test residuals both for normality and for autocorrelation. As far as the common normality test is concerned, Shapiro-Wilk test shows that residuals are not normal, however its drawback is that it checks the whole empirical distribution and in fact we mostly need fat tails to resemble those of the normal distribution. The graphical analysis of the Chart 4 suggests that fat tails of constructed model residuals are similar to those of the standard normal distribution. The empirical distribution is also symmetrical which together with the former lets accept the VAR model as far as this criterion is concerned.

As for autocorrelation of residuals, it is the Lagrange multiplier test which is efficient and often applied for testing it (Breusch and Pagan, 1980; Baltagi et al., 2012). According to its results, there is no correlation in the model (Table 10).

Another test used in the paper for diagnostics of autocorrelation was modified Portmanteau statistics (Ljung and Box, 1978) which shows results implying the same conclusions as for the Lagrange multiplier test (Table 11).

The fact that the autocorrelation of residuals does not exist was also confirmed by AC and PAC functions (Table 12).

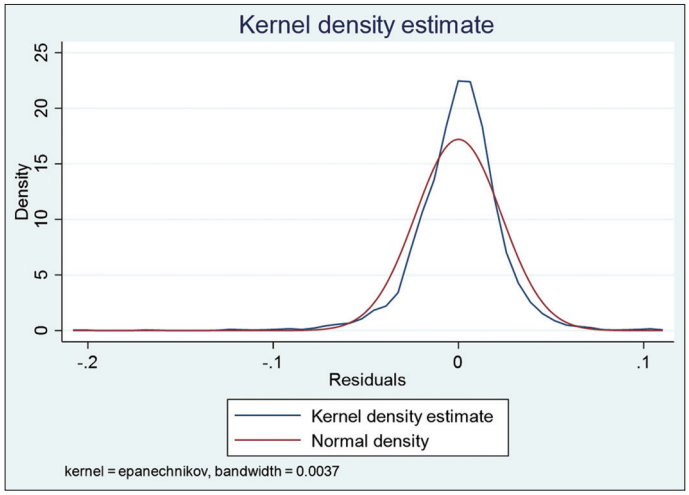
Taking into account the above made tests for autocorrelation of residuals, it can be stated that the constructed Unrestricted Vector Autoregression model is accurate as residuals are white noise. Therefore, it can be confirmed that crude oil together influences the

Table 8: Unrestricted VAR model results

lnSP500						
Variable	**Coefficient**	**Standard error**	**z**	**P>|z|**	**95% confidence interval**	
lnSP500						
Lag 1	–0.0817144	0.0253395	–3.22	0.001	–0.1313789	–0.0320499
Lag 2	0.0704626	0.0253329	2.78	0.005	0.020811	0.1201142
lnGBPUSD						
Lag 1	0.0436636	0.0439399	0.99	0.320	–0.0424569	0.1297842
Lag 2	–0.0793205	0.0439462	–1.80	0.071	–0.1654536	0.0068126
lnCrudespot						
Lag 1	0.0067596	0.0102639	0.66	0.510	–0.0133572	0.0268764
Lag 2	–0.020926	0.0102644	–2.04	0.041	–0.0410439	–0.000808
Constant	0.0016003	0.0005784	2.77	0.006	0.0004667	0.0027339
lnGBPUSD model						
Variable	**Coefficient**	**Standard error**	**z**	**P>**	**95% confidence interval**	
lnSP500						
Lag 1	–0.0119102	0.0145091	–0.82	0.412	–0.0403475	0.0165271
Lag 2	0.012772	0.0145053	0.88	0.379	–0.015658	0.041202
lnGBPUSD						
Lag 1	0.000388	0.0251595	0.02	0.988	–0.0489237	0.0496996
Lag 2	–0.0693581	0.0251631	–2.76	0.006	–0.1186769	–0.0200393
lnCrudespot						
Lag 1	0.0063923	0.005877	1.09	0.277	–0.0051264	0.0179109
Lag 2	0.0131583	0.0058773	2.24	0.025	0.001639	0.0246776
Constant	–0.0001105	0.0003312	–0.33	0.739	–0.0007596	0.0005386
lnCrudespot model						
Variable	**Coefficient**	**Standard error**	**z**	**P>|z|**	**95% confidence interval**	
lnSP500						
Lag 1	–0.001655	0.0624731	–0.03	0.979	–0.1241	0.12079
Lag 2	–0.040931	0.062457	–0.66	0.512	–0.1633444	0.0814824
lnGBPUSD						
Lag 1	0.0975417	0.1083313	0.90	0.368	–0.1147838	0.3098672
Lag 2	–0.0055563	0.1083471	–0.05	0.959	–0.2179126	0.2068001
lnCrudespot						
Lag 1	0.0223933	0.025305	0.88	0.376	–0.0272035	0.0719902
Lag 2	0.0026437	0.0253064	0.10	0.917	–0.0469559	0.0522434
Constant	0.000859	0.001426	0.60	0.547	–0.0019358	0.0036539

Source: Author's calculations

Chart 4: Distribution of residuals for the applied VAR model



Source: Author's study

Table 9: Granger causality Wald tests

Equation	Excluded	Chi2	df	Prob>chi2
lnSP500	lnGBPUSD	4.2593	2	0.119
lnSP500	lnCrudespot	4.5459	2	0.103
lnSP500	ALL	9.5471	4	0.049
lnGBPUSD	lnSP500	1.5814	2	0.454
lnGBPUSD	lnCrudespot	6.2796	2	0.043
lnGBPUSD	ALL	8.4242	4	0.077
lnCrudespot	lnSP500	0.43029	2	0.806
lnCrudespot	lnGBPUSD	0.81372	2	0.666
lnCrudespot	ALL	1.301	4	0.861

Source: Author's calculations

Table 10: Lagrange multiplier test results

Lag	Chi2	df	Prob>chi2
1	10.9865	9	0.27664
2	15.8505	9	0.07007

Source: Author's calculations

Table 11: Portmanteau test for white noise

Portmanteau (Q) statistic	Prob>chi2 (40)
50.7991	0.1178

Source: Author's calculations

Table 12: AC and PAC functions autocorrelation results

Lag	AC	PAC	Q	Prob>Q
1	0.0045	0.0045	0.03237	0.8572
2	–0.0005	–0.0005	0.03272	0.9838

Source: Author's calculations

American stock market. Simultaneously, results from the Granger causality Wald test suggest that the oil market impact on the stock market is done together with the GBP/USD currency rate.

5. CONCLUSIONS, DISCUSSION AND FURTHER STUDIES

As shown, there are no long term relations between the US stock market and WTI crude oil prices. Crude oil influences the stock market in the short run only. Nevertheless, it is not obvious if it does it by itself only or together with the currency market represented by GBP/USD. The relation does not go in another direction which means that the stock market has no impact on the oil market.

Such conclusions suggest that countries should promote activities aiming at achieving the stability of oil prices to promote the stability of stock markets which induces the steady economic development. Although from the point of the United States it could be rather difficult to influence the supply and demand of oil as it depends on many macroeconomic factors, oil prices also depend on speculators activities. Taking into consideration that there are many investment banks or hedge funds operating in the US and playing a role of market speculators, the paper can be advantageous for US authorities who should think about introducing the law which will reduce speculators role in the economy. This can be for example not letting them to be too big as the larger the capital is invested the stronger speculative effect appears.

The analysis is consistent with such studies as for example (Hwang and Kim, 2021) or (Arouri and Nguyen, 2012) where authors emphasize the role of the crude oil market in the stock market behavior, however apply different methods form the one used here. At the same time it has different conclusions than these presented in (Arouri and Rault, 2012) who notice the cointegration between the oil and the stock market or than the ones shown by Apergis and Miller, 2009 who do not find the impact of the oil market to the stock market. Contrary to it, this paper states that there is no long-term relation between these markets but crude oil prices fluctuations influence stock market prices in the short run. The new conclusion compared to so far existing research is also that it is not clear if this is the crude oil market itself or thanks to interactions with the GBP/USD market that it interrelates with the American stock market. The advantage of the study is a very long period of time which covers over 30 years, as well as using reliable research methods. The limitation of the study is using one specific market of oil (WTI) and one specific stock market (USA). However, American economy is the global one and influences the whole world economies and financial markets.

The subject with no doubts deserves further studies which could concentrate on checking if for other stock markets it is also crude oil together with some other asset (and not single) to be responsible for their fluctuations or crude oil itself. Maybe even if oil causes stock markets fluctuations, they may be stronger when it is considered together with some other assets? Besides, other control variables and different models could be applied. Future studies should go in this direction to answer the question posed.

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