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A Study of the Relationship Between the Gold Price, the Exchange Rate and the Stock Market Index Returns during the Current Crisis Period using DCC-GARCH and VAR DCC-GARCH Models. Comparative Analysis of Romania and Poland

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Abstract

The events of recent years had a significant impact on financial markets and the economy in general, causing increased volatility in many business sectors. The purpose of this study is to carry out a comparative analysis that aims to highlight the evolution trends of the volatility of the stock market indices from Romania and Poland, as well as two key variables, namely the exchange rate and the price of gold. The originality of this work lies in the case study carried out on the price of gold, the exchange rate, and the main stock market indices from Romania and Poland, which are two emerging countries from Eastern Europe. The results show an increased volatility between variables, as well as the existence of an inverse relationship, on the one hand, between gold index prices and exchange rates and, on the other hand, between gold prices and stock index returns. It was found that there is a direct relationship, synchronised in certain periods, between exchange rates and stock indices. The one-way relationship between the Romanian stock market indices and the price of gold, as well as between exchange rates (USD_RON and USD_PLN) and the price of gold, shows that the price of gold responds to the changes coming from these and not the other way around, which denotes a reluctance of investors who consider that there are more advantageous investments than those in gold.

Keywords: crisis period, multivariate GARCH, stock index return, gold price, exchange rate.

JEL Classification: C01, C12, C51, C52, C53, C55, C58, C61, C63, F47.

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1. Introduction

Gold is traditionally considered a safe investment during periods when negative economic events occur, when there are exchange rate fluctuations, as well as economic instability, which can lead to increased demand for gold. The paper aims to highlight the relationships and influences between the behaviour gold index and the main stock market indices from Romania (the BET index of the Bucharest Stock Exchange) and Poland (the WIG index of the Warsaw Stock Exchange), as well as the exchange rate of the two countries related to USD. The used datasets with daily observations are based on the closing prices of stock indices, gold and the exchange rate from 29.03.2010 to 27.03.2023, on which multivariate GARCH models have been applied, namely DCC-GARCH and VAR-DCC, which allowed us to generate graphs based on the wavelet technique. The objective of the paper is to analyse the gold index compared to changes in the main stock market indices and the exchange rate in the two countries, a fact useful in the decision-making process of investors in diversifying their portfolios. Although there are various studies in the economic literature on the relationship between gold prices and stock indices (Kumaraswamy, Abdulla, Panigrahi, 2023; Nafisi-Moghadam, Fattahi, 2022), which, through various GARCH models, show the persistence of gold prices volatility in India and other emerging countries as a result of using this asset as a safe haven. By investigating the relationship between gold and stock indices with multivariate and bivariate tests, it could be seen that gold is not a safe haven during a period of economic decline (Choudhry, Hassan, Shabi, 2015). There are studies showing that the price of gold can influence the exchange rate of the dollar, which can be an advantage or a disadvantage, depending on the investment strategy and objectives of the lead investor (Moussa, Mgadmi, Regaieg, Bejaoui, 2020), and there are also other studies showing that the price of gold plays a substantial role in creating pressure on the exchange rate of the dollar as well as the fact that there is a negative relationship between the exchange rate and the price of gold, the increase in the price of gold leading to the depreciation of the US dollar (Tsen, 2015). The importance of the paper, even if this topic has been addressed in the vast literature related to this field (Baur, Lucey, 2010), is given by the perspective that it can provide to investors through the analysis of the influence of gold, the exchange rate, and the stock markets in Romania and Poland, under the conditions the current global economic uncertainty, with armed conflicts at the border.

The main objective of this paper is to show that, by using multivariate GARCH econometric models, it is possible to capture the change over time in the variation of the volatility of the variables used, especially during the current unforeseen events in which gold is considered as a safe haven asset.

Moving onwards, the paper is structured as follows: the second section, in which some of the specialised works in the field are mentioned, the third section, in which the research methodology used is presented, and the fourth and fifth sections, which show the contribution of the work to the literature in the field, and the last section where the conclusions are presented.

2. Literature Review

In the economic literature, there are numerous papers on the relationship between gold and the stock markets of India, Pakistan, Malaysia, and other emerging countries. The main reason why these countries are chosen to conduct an economic analysis is that they have a strong tradition of holding gold as a form of investment and protection against inflation and currency volatility. Another reason could be that emerging countries are often more vulnerable to economic and financial crisis and their stock markets are less developed and more volatile than those in developed economies, making the relationship between gold and stock markets more visible.

By using various robust data analysis methods that generate useful insights into complex economic relationships, it could be seen that gold and oil prices have a major impact on stock markets (Shabbir, Kousar, Azra, Batool, 2020). The asymmetric impact between the volatilities of gold and oil prices on stock markets shows the existence of strong positive spillover effects in the case of developed countries and negative spillovers in the case of emerging economies, both on the long term, as well as on the short term (Raza et al., 2016). There are also contradictions in the specialised literature (Marwanti, Robiyanto, 2021), which, through studies conducted on the impact of gold and oil price volatility on stock markets, concluded that, in troubled times, gold represents a hedging asset in emerging countries. There are several studies suggesting that the price of gold can influence the exchange rate of the dollar and the conclusion was that the gold price could be a good way to observe the future performance of the exchange rate (Erb, Harvey, 2012).

Analysing in various papers the impact that the volatility of gold has on the exchange rate, it was found that, on the long term, gold can only represent a partial hedge against currency depreciation. In the short term, the price of gold can fluctuate significantly and unexpectedly, which can cause losses for investors seeking to hedge against currency depreciation (Wang, Thi, Lee, 2021). On the other hand, it has been demonstrated that when there is an increase in volatility in the economy during periods of crisis, metals such as gold can be considered useful for diversifying the portfolio. Referring to the 2008 crisis period, the negative values of the correlations between gold and stock indices showed that gold can serve as a refuge (Siemaszkiewicz, 2020).

3. Research Methods

This study, by using the VAR-DCC-GARCH method, which is an extension of the DCC-GARCH method, focused on modelling the interdependencies between the used variables, namely the price returns of the BET and WIG stock indices, the gold price returns, as well as the USD exchange rate against the currencies from Romania and Poland, as we wanted to showcase how the volatility of gold affects the volatility of emerging stock markets and the USD exchange rate in those countries.

In their paper, Engle and Sheppard (2001) introduced the concept of DCC-GARCH, which allowed the modelling of time-varying conditional correlation.

Cappiello et al. (2006) added to the model proposed by Engle by introducing an asymmetric DCC-GARCH model. In this study we have approached the VAR-DCC-GARCH version. Engle (2002) defined the covariance matrix in DCC-GARCH as follows:

$$H_t = D_t R_t D_t \qquad (1)$$

The model proposed by Engle (2002) differs from that of Bollerslev (1990) in that R can vary, and the correlation of the DCC-GARCH model is characterised by the formula:

$$Q_t = (1 - \sum_{m=1}^{M} a_m - \sum_{n=1}^{N} b_n)\overline{Q_t} + \sum_{m=1}^{M} a_m a_{t-1} a_{t-1}^T + \sum_{n=1}^{N} b_n Q_{t-1} \qquad (2)$$

We have studied the degree of interdependence between gold, stock indices, and exchange rates by applying the wavelet technique for graphs, which provides a broader vision of the periods in which there is influence and persistence of the interdependence between the variables. This often-used method has a graphical interpretation that is based on the colours and the meaning of the arrows, as the warmer the colours of the graph are (red or orange), the greater the interdependence between the variables will be. To realise the wavelet technique, first we had to apply the wavelet transformation, which is characterised by the formula:

$$X(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} \overline{\left(\frac{\Psi(t-b)}{a}\right)} x(t) \, dt \qquad (3)$$

4. Description of the Data

To determine the relationship between the gold price, exchange rates, and stock indices in Romania and Poland, we used data sets with daily frequency for the period 29.03.2010-27.03.2023. The analysis was performed on the closing prices of the gold index, the BET and WIG stock indices, and the exchange rates, based on which the classical return calculation formula was applied (the logarithmic ratio version). The data series was collected from the Reuters platform, the BNR and the Investing.com websites.

Figure 1. The evolution of the data series from March 2010 to March 2023
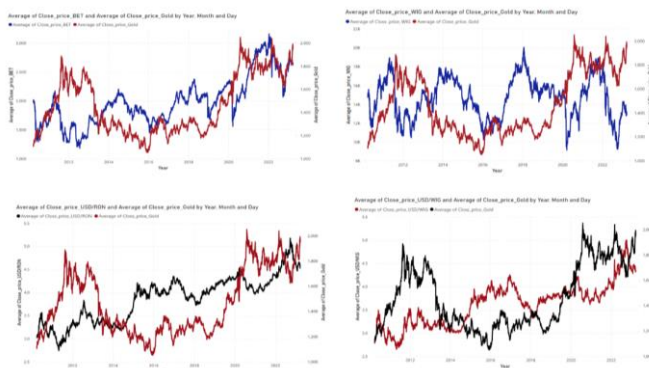
Source: Author's own calculations, based on data available on the websites.

Table 1. Correlation between variables

	Gold	BET	USD_RON	WIG	USD_PLN
Gold	1.0000				
BET	0.1154	1.0000			
USD_RON	-0.1542	-0.3491	1.0000		
WIG	0.1606	0.5788	-0.3207	1.0000	
USD_PLN	-0.2156	-0.5254	0.3458	-0.7216	1.0000

Source: Author's own calculations.

In Figure 1, we have graphically illustrated the time evolution of the analysed data series between March 2010 and March 2023. An increased volatility between variables is observed, as well as an inverse relationship between gold stock index prices and exchange rates. In terms of the degree of correlation, we can say that there is a degree of correlation between BET and WIG, as well as between the two exchange rates. There is also a small degree of positive correlation between the returns of the gold price and the returns of the two stock indices.

5. Results and Discussion

The descriptive statistics carried out, the results of which are illustrated in Table 2, showed that during the analysed period there was an average increase in the returns of the gold price, the BET index, as well as the exchange rates, apart from the WIG stock index. The data series has negative skewness except for the two exchange rates, which have positive skewness. The value of the kurtosis coefficient shows that the data comes from a leptokurtic distribution, and, according to the ADF (Augmented Dickey Fuller) test, at a significance level of 95%, the series of data that were used are stationary.

Table 2. Summary statistics

	Gold	BET	USD_RON	WIG	USD_PLN
Mean	0.0181	0.0094	0.0134	-0.0039	0.0131
Median	0.0313	0.0596	0.0030	0.0319	-0.0130
Min	-9.8205	-12.9450	-3.3455	-15.5473	-4.1598
Max	5.7775	11.4576	3.1997	7.9914	5.1454
Std	1.0437	1.3577	0.6121	1.6191	0.8169
Jb	4739.1	18191	907.32	6983.3	1402.9
Skewness	-0.5659	-0.8908	0.2110	-0.7922	0.3963
Kurtosis	5.9337	11.7020	2.6081	7.1600	3.1887
ADF	-14.632***	-13.057***	-14.006***	-14.51***	-14.776***

*** significant at 1% level, ** significant level at 5% level, * significant level at 10% level
Source: Author's own calculations.

To determine the relationships between the analysed variables and predict their values in the future, we have performed an estimation of the conditional average of the VAR DCC-GARCH model, the propagation coefficients of the own average being very important

both in understanding the interdependence between financial variables and in the risk assessment of the propagating shocks between them. From the results obtained in Table 4, it can be seen how the propagation coefficients of the own average for BET registered a positive and significant value (0.0730), for the USD_RON exchange rate it showed a negative and significant value (-0.1398) and for gold a negative but insignificant value (-0.0237). The propagation coefficient of the mean for WIG was positive (0.0361), but statistically insignificant. For the USD_PLN exchange rate, the propagation coefficient was negative (-0.0623), but significant, and for gold it was negative (-0.0298) and statistically insignificant.

Table 3. Estimates of conditional mean VAR model

	Coefficients			
Romania				
	c_1	φ_{11}	φ_{12}	φ_{13}
BET	0.0068	0.0730***	0.0838***	0.0463***
	c_2	φ_{21}	φ_{22}	φ_{23}
USD_RON	0.0181	-0.1433***	-0.1398***	-0.0786***
	c_3	φ_{31}	φ_{32}	φ_{33}
Gold	0.0182	0.0125	0.0233	-0.0237
Poland				
	c_1	φ_{11}	φ_{12}	φ_{13}
WIG	-0.0036	0.0361	-0.0525	0.0311
	c_2	φ_{21}	φ_{22}	φ_{23}
USD_PLN	0.0145	-0.0281***	-0.0623***	-0.0325***
	c_3	φ_{31}	φ_{32}	φ_{33}
Gold	0.0187	0.0283	0.0066	-0.0298

*** significant at 1% level, ** significant level at 5% level, * significant level at 10% level
Source: Author's own calculations.

The results showed, in the case of the BET index, that there is a significant positive one-way relationship between the BET index and the price of gold, which means that there is a significant correlation between these two variables, but this correlation is only valid in one direction. In other words, an increase in the performance of the stock market in Romania may lead to an increase in the price of gold, but a decrease in the price of gold will not have a significant effect on the performance of the stock market. On the other hand, in the case of the WIG index, we can say that there is no relationship or significant correlation between the gold index and the stock market index. A unidirectional, but negative, relationship is also found in the case of the USD_RON and USD_PLN exchange rates on the price of gold, which signifies a trend, namely: an increase in the exchange rate could lead to a decrease in the price of gold. To observe the relationships between the studied variables, we have used two models that are part of the multivariate GARCH family, namely the DCC-GARCH model and the VAR-DCC-GARCH model. These models are often used in such studies due to their ability to model the volatility of the dynamic relationships between the studied time series.

Table 4. Results of DCC-GARCH and VAR DCC-GARCH models

Model	DCC-GARCH				
	Coefficients				
Variables	Ω	α_1	β_1	DCC α	DCC β
Romania					
BET	0.0545***	0.1085***	0.8631***		
USD_RON	0.0017***	0.0383***	0.9573***	0.0184***	0.0266***
Gold	0.0160	0.0361***	0.9492***		
Log-likelihood	-11701.97				
Poland					
WIG	0.0387***	0.0743***	0.9117***		
USD_PLN	0.0051***	0.0616***	0.9313***	0.0280***	0.9588***
Gold	0.0160	0.0361***	0.9492***		
Log-likelihood	-12152.53				
VAR DCC-GARCH					
Romania					
BET	0.0253***	0.1125***	0.8849***		
USD_RON	0.0012***	0.0442***	0.9532***	0.0184***	0.9525***
Gold	0.0048	0.0319***	0.9657***		
Log-likelihood	-11524.1				
Poland					
WIG	0.0032	0.0621***	0.9300***		
USD_PLN	0.0040***	0.0618***	0.9339***	0.0266***	0.9621***
Gold	0.0068***	0.0321***	0.9632***		
Log-likelihood	-12207.15				

*** significant at 1% level, ** significant level at 5% level, * significant level at 10% level

Source: Author's own calculations.

The results obtained above, following the application of the two multivariate GARCH models, can be concluded by the fact that the DCC-GARCH model shows, for both countries, how the coefficient of the var-covar matrix parameter Ω is positive and statistically significant, except for gold yields. In the case of the VAR-DCC-GARCH model, for Romania, we have observed a significant positive value of the parameter Ω for the BET and USD_RON indices, but a positive and insignificant value for gold. In Poland's case, a positive and significant value is found only in the case of gold. Looking at the coefficients of the GARCH model (α_1 and β_1) we've noticed that their sum, both in the case of the DCC-GARCH model and in the case of the VAR-DCC-GARCH model, is a subunit value, so a pronounced GARCH effect is present. From the point of view of the $dcc\alpha$ and $dcc\beta$ parameters, we can see that they are statistically significant for both models, so what can be concluded is that a strong and long-lasting effect of the volatility of the time series covariance is present, a conclusion drawn based on the very high values

of the $dcc\beta$ coefficient. To see which model better illustrates the correlation between the variables and better models the volatility between the variables, we have used some measures to determine which model fits the data series better based on the principle of choosing the model with the lowest values of the MSE, RMSE and MAE parameters.

Table 5. The performance of the models

	DCC-GARCH Model		VAR-DCC-GARCH Model	
	Romania	Poland	Romania	Poland
MSE	0.9491	2.4196	0.9298	2.4163
MAE	0.6463	1.0586	0.6338	1.0562
RMSE	0.9742	1.5555	0.9642	1.5544

Source: Author's own calculations.

The results obtained above show that the VAR -DCC-GARCH model is a better model than the DCC-GARCH model.

Figure 2. VAR DCC-GARCH - Conditional Correlation for Romania and Poland
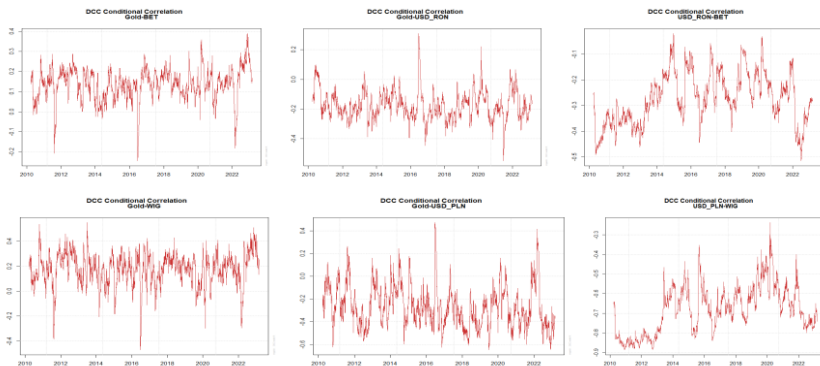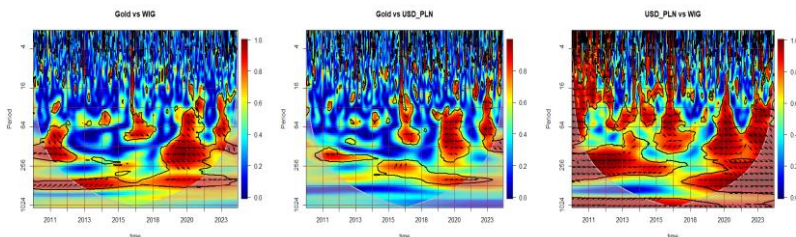

Source: Author's own calculations.

The graphs illustrated by the Wavelet technique, which allows the observation in detail of the influences between the analysed data series, show the results obtained with the VAR-DCC-GARCH model, namely that there is a high, persistent volatility of the covariance of the time series over time.

Figure 3. Wavelet technique – Romania
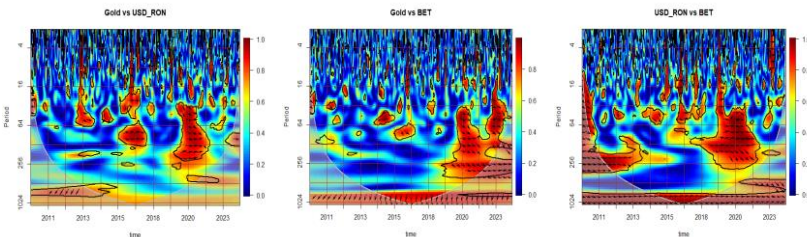
Source: Author's own calculations.

Figure 4. Wavelet technique – Poland

Source: Author's own calculations.

Figure 3 presents the case of Romania, namely the correlation between the variables BET, USD_RON, and gold for the analysed period. In the case of the correlation between gold and the stock market index, it can be observed that the blue colour spectrum is predominant, which means that on the short term there is no significant correlation between the two variables, instead, on the medium term, in the period 2020-2023, with the events that have affected the entire global economy, the relationship between them has changed. Thanks to the arrows pointing down and to the right, it can be observed that there is an inverse relationship between the two data series. The same can be said about the relationship between the RON_USD exchange rate and gold, namely that, starting with the 2019-2020 period, more prominent correlations can be observed between the two variables, but, on the medium term, the relationships are inverse (showing arrows pointing to the lower right). We cannot say the same thing about the relationship between the exchange rate and the BET stock index, where there is a positive relationship in which the two variables are synchronised.

In the case of Poland (Figure 4), we can observe a strong correlation between the stock index and gold in the period 2019-2023, being an inverse relationship, preceded by a short period in which the relationship between the two variables was synchronised. The relationship between the USD_PLN exchange rate and gold shows, in the medium term, a synchronised relationship between the two variables that is visible in the period 2020-2021. Regarding the relationship between the USD_PLN exchange rate and the WIG stock index, it can be seen that there is a strong relationship (the warm colour spectrum dominates the graph) on the short term, as well as on the medium and long term, in the period 2010-2013 and in the period 2015- 2023, a relationship marred by moments in which the series were strongly synchronised, but in the 2020-2023 interval there were also periods in which the series had an inverse relationship.

6. Conclusions

The current paper uses two known econometric models, due to their efficiency in terms of modelling volatility and capturing the relationships between variables, and proposes a comparative analysis between two emerging countries, namely Romania and Poland, through which the correlation between the volatility of the prices of the BET and WIG stock market indices, the exchange rates related to the two economies

and gold is evident. The results show that there is an increased volatility between the variables, as well as an inverse relationship, on the one hand, between the prices of the gold index and the related exchange rates of the two countries and, on the other hand, between the prices of gold and the returns of the stock indices. It was found that there is a direct relationship, synchronised in certain periods, between exchange rates and stock indices. The inverse relationship between gold stock index prices and the exchange rate shows that an increase in gold prices can lead to a depreciation of the local currency, which can reflect fluctuations in the international foreign exchange market. Conversely, an increase in the value of the national currency can make that country's products and services more expensive than those of other countries, which can reduce exports and have a negative impact on the country's economy, economic changes that can influence the price of gold in a negative way.

The existence of the correlation between BET and WIG, as well as between the two exchange rates, and the existence of a small degree of positive correlation between the gold price returns and the returns of the two stock market indices, as well as the fact that, following the estimation of the conditioned average between the stock market index BET and the price of gold and between exchange rates and the price of gold, it was found that there is a unidirectional relationship showing that the price of gold responds to the changes coming from those variables and not vice versa, thus signifying a reluctance of investors who consider that gold does not represent an advantageous investment in times of crisis and are in favour of other investments considered advantageous. From the perspective of Poland's WIG index, it is observed that there is no relationship between it and the gold index, but only a one-way relationship between the exchange rate and the price of gold. By performing the DCC-GARCH and VAR-DCC-GARCH models, we have found that the best model that captures volatility and the relationships between variables is the VAR-DCC-GARCH model. From the results obtained, we have found a strong and long-lasting effect of the volatility of the time series covariance, as well as a strong GARCH effect. Conditional correlation plots provide useful insight into the nature of these relationships and how they vary over time, while wavelet analysis provides a more detailed perspective that helps identify relationships that are more difficult to see in other types of graphs. The persistent medium-term inverse relationship between the price of gold and stock indices over the period 2020-2023 can be used by investors and portfolio managers, as it suggests that gold can be an effective hedge against financial market volatility, but there are other factors that can influence the price of gold, such as monetary policy, interest rates, and geopolitical events.

References

[1] Baur, D.G., Lucey, B.M. (2010). Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold, *The Financial Review*, 45(2), 217-229.

[2] Bollerslev, T. (1990). Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized Arch Model, *The Review of Economics and Statistics*, 72(3), 498-505.

[3] Cappiello, L., Engle, R.F., Sheppard, K. (2003). Asymmetric dynamics in the correlations of global equity and bond returns. European Central Bank, *Working Paper*, No. 204.

[4] Choudhry, T., Hassan, S., Shabi, S. (2015). Relationship between gold and stock markets during the global financial crisis: Evidence from nonlinear causality tests, *International Review of Financial Analysis*, 41(C), 247-256.

[5] Engle, R.F., Sheppard, K. (2001). Theoretical and Empirical properties of Dynamic Conditional Correlation Multivariate GARCH. National Bureau of Economic Research, *Working Paper*, No. 8554.

[6] Engle, R. (2002). Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models, *Journal of Business & Economic Statistics*, 20, pp. 339-350.

[7] Erb, C.B., Harvey, C.R. (2012). The Golden Dilemma, *Financial Analysts Journal*, 69(4), 10-42.

[8] Kumaraswamy, S, Abdulla, Y., Panigrahi, S.K. (2023). Will Gold Prices Persist Post Pandemic Period? An Econometric Evidence, *International Journal of Financial Studies*, 11(1), 8.

[9] Marwanti, M.M., Robiyanto, R. (2021). Oil and gold price volatility on indonesian stock market in the period of COVID-19 pandemic, *Journal of Management and Entrepreneurship*, 23(2).

[10] Moussa, W., Mgadmi, N., Regaieg, R., Bejaoui, A. (2020). The relationship between gold price and the American financial market, *International Journal of Finance & Economics*, 26(4), 6149-6155.

[11] Nafisi-Moghadam, M., Fattahi, S. (2022). A Hybrid Model of VAR-DCC-GARCH and Wavelet Analysis for Forecasting Volatility, *Eng. Proc.*, 18(1), 6.

[12] Raza, N., Shahzad, J., Tiwari, A., Shahbaz, M. (2016). Asymmetric impact of gold, oil prices and their volatilities on stock prices of emerging markets, *Resources Policy*, 49.

[13] Siemaszkiewicz, K. (2021). Safe haven instruments – a comparison between the global financial crisis and the COVID-19 pandemic. Econometrics, Ekonometria, *Advances in Applied Data Analysis*, 25(4).

[14] Shabbir, A., Kousar, S., Batool, S.A. (2020). Impact of gold and oil prices on the stock market in Pakistan. Journal of Economics, *Finance and Administrative Science*, 25(50), 279-294.

[15] Tsen, W.H. (2015). Exchange Rate and Gold Price: Evidence from Malaysia, *Labuan Bulletin of International Business and Finance* (LBIBF), 12.

[16] Wang, K.-M., Thi, T.-B. N., Lee, Y.-M. (2021). Is gold a safe haven for the dynamic risk of foreign exchange?, *Future Business Journal*, Springer, 7(1), 1-17.