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Time Varying Causality between Oil Price and Precious Metals : Bootstrap Rolling Windows Granger Causality Approach

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ABSTRACT

The study of the interaction between oil price and precious metals occupies a research activity and pushes various economists to seek implications both on the economic and political level. It is also important to take into account the evolution of the oil and precious metals markets throughout the period of the COVID-19 pandemic and recently the Ukraine-Russian war. In this paper, we examine the link between the oil price and three types of precious metals namely gold, silver and platinum using the rolling window Granger bootstrap causality method. The study is conducted on the monthly data of oil price and precious metals from the period span from January, 2004 to May, 2022. The empirical results lead to a strong unidirectional causality between oil and platinum and absence of causality between oil and the other two metals.

Keywords: Oil Price, Platinum, Silver, Gold, Causality, Time Varying
JEL Classifications: C58, F65, G15

1. INTRODUCTION

Gold and other precious metals have always been used as a hedging tool against risk and represent a store of value to defend currencies since the collapse of the Bretton-Wood system and the global financial system. Awareness of precious metals as an investment vehicle has increased, particularly after the financial crisis of 2008-2009, due to the increased financialization of the commodity market.

Energy and precious metals play an important role in the global economy in terms of trade, economic activity and wealth accumulation. In particular, these commodity sectors represent an attractive investment driver (Fattouh et al., 2013; Cheng and Xiong, 2014). Oil represent a major resource in the production process. Energy price shocks can be transmitted to agricultural commodities through the expansion of biofuels, which has accelerated since the early 2000s (see, among others, Zilberman et al., 2013).

Oil presents itself as a crucial tool for the production of goods and energy with a daily consumption level of approximately 93 million barrels/day in 2015. Crude oil production is centralized with OPEC as the main world organization whose members control about 73% of its total production. Current literature documents the importance of global oil supply and demand and their substantial impact on the real economy as it affects price formation and inflation (Kilian, 2009). This has implications for investment strategies, as any shock in the crude oil market tends to ripple through financial markets. Any change in crude oil prices can therefore lead to price changes in traditional asset markets, including other commodity markets, namely precious metals.

In the economic and financial literature, the interaction between commodity prices is a crucial topic. Various empirical studies have tried to investigate these types of interactions using various empirical methodologies. The current literature that studies how the price of oil affects stock indices and precious metals can be categorized into several areas: Volatility dependencies, economic transmission, market efficiency and price co-movements, otherwise said the similar movements.

In the financial literature, many studies consider the crude oil price as a proxy representing the energy market in the interaction energy price - precious metals. In this context, several approaches are considered. Most studies reveal a significant relationship between these two markets, leading to the conclusion that precious metals are considered as hedging assets and a safe haven against variations in energy prices (Hammoudeh and Yuan, 2008; Zhang and Wei, 2010; Charlot and Marimoutou, 2014; Reboredo et al., 2016; Mokni et al., 2020, among others).

Several methodological approaches are used in the energy-precious metals link. Granger causality is frequently used. As an example, Zhang and Wei (2010) use the causality between crude oil and gold markets over the period between January 2000 and March 2008 and report evidence of a consistent trend between crude oil prices and gold.

In the same context, Simakova (2011) uses the same methodology, as well as Johansen's cointegration test and the VECM model, to indicate a long-term relationship between oil and gold. Bildirici and Turkmen (2015) analyze the relationship between oil and precious metals namely gold, silver and copper using cointegration and non-linear causality tests over the period between 1973 and 2012. Their results show evidence of a two-way causality between oil prices and precious metals.

In another field of empirical analysis, Dutta et al. (2019) analyze the relationship between the volatilities of oil, gold and silver prices and prove the presence of a bidirectional and symmetric nonlinear causality between the price of oil and gold. Additionally, Hernandez et al. (2019) apply a quantile-based approach and show that agricultural commodities and precious metals have the ability to act as a safe haven against downside risk in the oil market.

Recently, Shafiullah et al. (2021) examine the causal interactions between oil prices and precious metals using the quantile causality test. The data used covers the period from 1990 to 2019. They find that upward and downward movements in metal prices have no predictive power on oil prices.

2. EMPIRICAL METHODOLOGY

2.1. Bootstrap Full-sample Causality Test

We adopt the rolling window Granger bootstrap causality test proposed and introduced by Balcilar et al. (2010). This method has been considered by various works such as those of Su et al. (2021), Sun et al. (2021) and by Minlah et al. (2021). We adopt the test of non-causality in the sense of Granger introduced by Engle and Granger (1987) based on the bivariate VAR model. It is suggested in the literature that this test verifies whether the information relating to a variable makes it possible to improve the prediction of another variable and vice versa. Classical Granger causality test statistics i.e. Wald test, LR likelihood ratio test and Lagrange multiplier (LM) test do not exhibit a standard asymptotic distribution when the series is I(1) or not stationary in level. Empirical estimation of the VAR model by the Granger causality test will be more difficult. Therefore, we perform Toda and Yamamoto's (1995) modified Wald test of the bivariate VAR model on rolling window subsamples. A disadvantage of standard Granger causality tests is that they are not suitable for small samples and can produce non-asymptotic critical values. To solve this problem, we use the residual-based (RB) bootstrap method advanced by Shukur and Mantalos (2004). Shukur and Mantalos (2000) report that modified LR tests on small samples provide better power and size properties even in small samples. Thus, we use the modified LR method based on RB to study the causal relationship between precious metals namely (GOLD), (PLATINUM) and (SILVER) and oil price (WTI).

The equation for the bivariate VAR model is as follows:

$$y_0 = \varnothing_0 + \varnothing_1 y_{t-1} + ... + \varnothing_p y_{t-p} + \mu_t,\ t = 1, 2, ...T \tag{1}$$

Where $(\varepsilon_{1t}, \varepsilon_{2t})$' is the white noise process with zero mean and covariance matrix. The optimal lag is determined by referring to the SBIC information criterion.

$y_t = (OP_t, PM_t)$'. Where, OP is the oil price and PM is all of the precious metals. Using two sub-vectors, equation (1) is written as follows:

$$\begin{Bmatrix} OP_t \\ PM_t \end{Bmatrix} = \begin{Bmatrix} \varnothing_{10} \\ \varnothing_{20} \end{Bmatrix} + \begin{Bmatrix} \varnothing_{11}(L)\varnothing_{12}(L) \\ \varnothing_{21}(L)\varnothing_{22}(L) \end{Bmatrix} \begin{Bmatrix} OP_t \\ PM_t \end{Bmatrix} + \begin{Bmatrix} \mu_{1t} \\ \mu_{2t} \end{Bmatrix} \tag{2}$$

Where $\varnothing_{ij}(L) = \sum_{k=1}^{p} \varnothing_{ij,k} L^k$ and the lag operator (L) is expressed as follows: $L^k x_t = x_{t-k}$.

Referring to equation (2), when $\varnothing_{12,k} = 0$, oil does not cause precious metals in the sense of Granger. In addition when $\varnothing_{21,k} = 0$, metals do not cause the oil price in the Granger sense.

2.2. Parameter Stability Tests

It is suggested in the empirical literature that the VAR model parameters indicate instability when the full sample data is marked by the presence of the structural changes (Su et al., 2019). Indeed, Balcilar and Ozdemir (2013) assert that the sample marked by the presence of a high number of observations leads to structural mutations that occur in the components variables of the complete sample. Thus, the interaction between the two variables shows an unstable effect over the sampling period.

To overcome the instability problem, stability tests of short-term parameters namely, Sup-F, Exp-F and Mean-F (Andrews, 1993; Andrews and Ploberger, 1994) and stability test Lc with the long term (Nyblom, 1989; Hansen, 1992) must be evaluated. If the parameters vary over time, this indicates that we should use the subsample test to study the causal Granger relationship between precious metals and oil.

2.3. Bootstrap Sub-sample Rolling-window Causality Test

When the parameter instability hypothesis is not accepted, Balcilar et al. (2010) suggest dividing the entire time series into subsamples based on the sliding window width l. Wang et al. (2020) indicate that this approach takes into account the variation of the causal relationship between the variables and the presence of instability due to structural changes. To investigate the causal relationship between variables in the subsamples, the modified RB-based LR test is performed. The bootstrap P-values and LR statistics for the T-1 subsamples allow us to identify temporal variations in the causal relationship between the two series.

$N_b^{-1}\sum_{k-1}^{p}\hat{\varnothing}_{12,k}^{*}$ and $N_b^{-1}\sum_{k-1}^{p}\hat{\varnothing}_{21,k}^{*}$ denote the average of a large number of estimates, indicating the impact of oil price on precious metals and the effect of metals on oil, respectively. Bootstrap estimates from VAR models are $\hat{\varnothing}_{12,k}^{*}$ and $\hat{\varnothing}_{12,k}^{*}$.

N_b represent the number of bootstrap repetitions. We calculate the 90% confidence intervals, where the lower and upper bounds are equal to the 5th and 95th quantiles of each of the $\hat{\varnothing}_{12,k}$ and $\hat{\varnothing}_{12,k}$.

3. DATA AND PRELIMINARY ANALYSIS

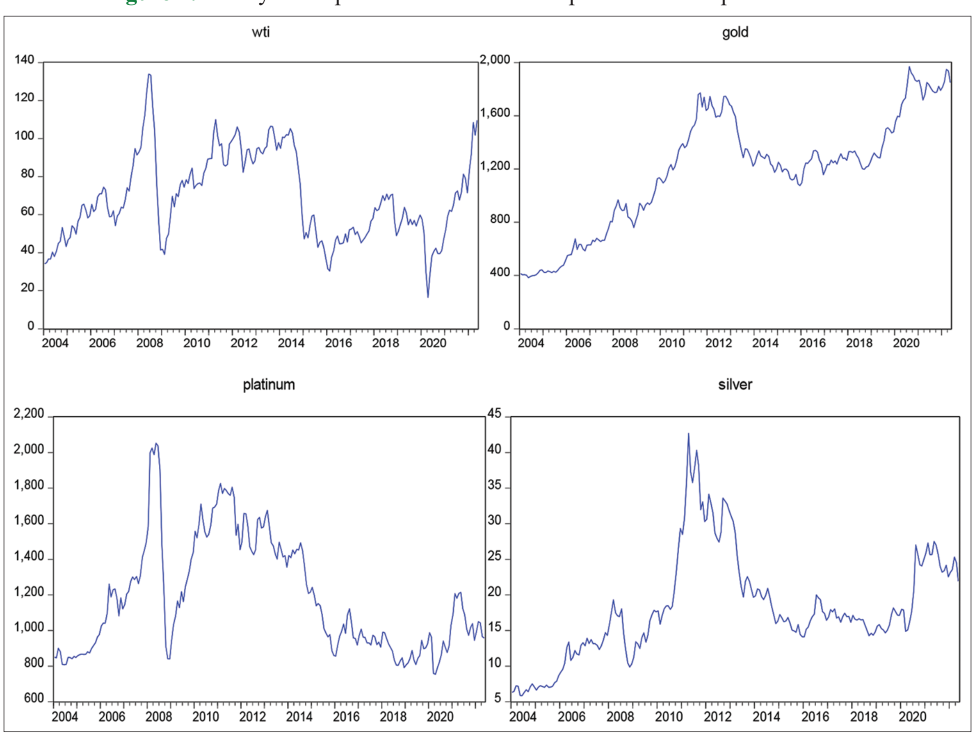
This article is the subject of an empirical modeling of the causal links between the oil price (WTI) considered as a reference index and three types of precious metals, namely (GOLD), (SILVER) and (PLATINUM). WTI is mixed in the United States and investors are consistent with various changes detected in the US oil markets. The data used are monthly. The study period runs from January 2004 until May 2022. This period is marked by the emergence of large-scale economic and financial crises such as the global financial crisis, the health crisis and currently the Russian war which caused geopolitical instability. Precious metals are extracted from the site: World Bank (2020) commodity database and oil is extracted from the site: www.eia.gov.

Figure 1 traces the dynamic profile and trends in the price of oil and precious metals used in our study. The movements observed in the price of crude oil indicate peaks of great importance. There are up-trends followed by down-trends and vice versa. The first peak observed was in 2008, the period of the global subprime crisis which affected the real estate sector in the United States thanks to household insolvency. The second peak observed is located in 2016 which is related to the oil crisis. The third peak is observed during the year 2020 marked by the Covid-19 pandemic which caused disturbances and imbalances in various markets, namely the foreign exchange market and the oil market. The last peak is located in the year 2022. This period saw the Russian war. This country has proposed selective and strict standards in the United States and it has used the Rubble as a reference currency.

Precious metals are also marked by up-trends followed by down-trends and vice versa. As part of portfolio diversification, investors use gold as a risk hedging strategy in times of turbulence. The function of gold has been weakened since the collapse of the Bretton-Wood's system. Gold is crucial for governments and central banks because it can be used as reserves to defend currency value. Indeed, it protects against the risk of inflation and against the risk of financial instruments. In the context of economic uncertainty, gold is considered as a hedging tool against the uncertainty of the global financial system.

Table 1 reports the descriptive statistics and the preliminary tests of the different variables used. Normality, skewness and kurtosis tests are performed. We observe that the average price of oil is around 68 dollars. It is observed that the average prices of precious metals are around 1184 for gold, 1185 for platinum and 18 for silver. Note that platinum represents the greatest

Figure 1: The dynamic profile and trends in the price of oil and precious metals



difference between the minimum value and the maximum value. On the other hand, the small difference is detected for silver. The value of the standard deviation makes it possible to measure the degree of volatility of the variables and the level of market risk. The low value of standard deviation is observed for silver indicating its low volatility. Gold is found to be the most volatile. The value of skewness gives information on the degree of asymmetry of the empirical distribution of the variables. Skewness values are generally positive with the exception of gold. This positivity justifies that the distribution of the variables is asymmetrical and spread to the right. The Jarque-Bera statistic allows the significant rejection of the normality hypothesis. In addition, reported results indicate a kutosis value >3 for silver. This result indicates the leptokurtic nature of empirical distribution and the occurrence of extreme values. By observing the unit root tests (ADF and PP), we see that the variables are I(1) or stationary in difference.

4. EMPIRICAL RESULTS

As part of the previous section, we tested the stationarity of the variables. Referring to equation (2), the bivariate VAR model composed of two variables namely the oil price and precious metals is used to study the causality. Based on the SBIC information criterion, the optimal lag chosen is of order 1. The main objective is to discuss the results of the modified LR tests based on the RB, the parameter stability tests and the causality tests. In order to empirically study the causal interaction between precious metals and the oil price, we chose a window size of 24 observations.

Table 2 reports the results of the Granger causality test between the oil and precious metals while considering the full sample based on the modified LR causality study. By observing the bootstrap P-values, we admit the absence of causality between WTI and

Table 1: The descriptive statistics and the preliminary tests

Tests	WTI	GOLD	PLATINUM	SILVER
Panel A: Descriptive statistics				
Mean	68.9731	1184.950	1185.883	18.2134
Maximum	133.9271	1968.630	2052.450	42.6959
Minimum	16.5200	383.7790	753.8600	5.8618
Std-Dev	22.7262	430.8702	319.6902	7.4665
Skewness	0.3992	−0.2638	0.7185	0.7636
Excess Kurtosis	2.4329	2.1877	2.5157	3.4672
Jarque-Bera	8.8307**	8.6395**	21.1763*	23.4870*
Prob	0.0120	0.0133	0.0000	0.0000
Panel B: Unit root test				
ADF-test				
Level	−2.9346	−1.7380	−2.8289	−2.1932
Prob	0.1537	0.7310	0.1885	0.4905
First difference	−10.0439*	−11.9172*	−10.6193*	−10.7635*
Prob	0.0000	0.0000	0.0000	0.0000
PP-test				
Level	−2.6376	−1.5690	−2.6514	−1.9470
Prob	0.2641	0.8021	0.2581	0.6263
First difference	−10.0906*	−11.8182*	−10.5982*	−11.5998*
Prob	0.0000	0.0000	0.0000	0.0000

*and **denotes the significance at 1% and 5%

Table 2: Full sample granger causality tests: Bootstrap LR test

			Pair (WTI-GOLD)			
Test		H0: WTI ne cause pas GOLD au sens de Granger			H0: GOLD ne cause pas WTI au sens de Granger	
	Statistics		P-value	Statistics		P-value
Bootstrap LR-Test	1.0569		0.6100	2.0653		0.2800
			Pair (WTI-PLATINUM)			
Test		H0: WTI ne cause pas PLATINUM au sens de Granger			H0: PLATINUM ne cause pas WTI au sens de Granger	
	Statistics		P-value	Statistics		P-value
Bootstrap LR-Test	15.8089***		0.0100	4.6298		0.1200
			Pair (WTI-SILVER)			
Test		H0: WTI ne cause pas SILVER au sens de Granger			H0: SILVER ne cause pas WTI au sens de Granger	
	Statistics		P-value	Statistics		P-value
Bootstrap LR-Test	3.8685		0.2500	3.9304		0.1800

***Denotes significance at 1%. *P* values are calculated using 1000 bootstrap repetitions

GOLD and between WTI and Silver. However, the causality between oil and platinum is unidirectional. This result confirms that WTI causes in the sense of granger platinum at the 1% level.

An increase in oil prices leads to an increase in platinum prices. Including platinum futures in a portfolio allows investors to enhance equity returns during bull markets. However, this strategy is no longer valid during bear markets since the platinum market reacts strongly following a drop in oil prices. In this case, investing in platinum is not an effective choice, because it fuels risks and offers a much lower return. This result is confirmed by Jain and Ghosh (2013).

For the purpose of verifying the evidence of structural changes, parameter stability tests seem necessary. In this framework, Zeileis et al. (2005) stipulates that the short-term causal link can be neglected. The results of the stability tests are reported in Table 3. The observation of the results indicates that the Sup-F statistics show the existence of a brutal and sudden structural change in the GOLD equation and in the VAR system at one 1% level. The other two statistics namely the Ave-F and Exp-F check that the data of the GOLD equation and the VAR model can change in a progressive way with time at a level of 1%. The Lc statistic proves that the estimated parameters of the VAR model are unstable. This instability of the short-term parameters leads us to use the rolling-window Granger causality method while considering bootstrap subsamples. Considering the causal relationships between oil price and the other two precious metals, namely platinum and silver, we see the same empirical evidence.

Figures 2 and 3 trace the value of the bootstrap probability as well as the size and direction of the impact and influence of the crude oil on gold and the opposite effect, namely the impact of gold on oil. The observation of this figure indicates the significant rejection at a level of 10% of the null hypothesis according to which the oil price does not cause in the sense of Granger the gold and this during several periods of sub-sample and specifically when the P-values are located below the horizontal red dotted line. The rejection of the null hypothesis is specified for the following time periods: 2008M06-2008M12; 2010:M08-2010M09; 2014M01-2014M10; 2016M01-2016M03 and 2020M07-2020M08. As for the influence of gold on the WTI, this same figure shows that the null hypothesis of no causality is rejected during the following two sub-periods: 2014M03-2015M02 and 2015M04-2015M10.

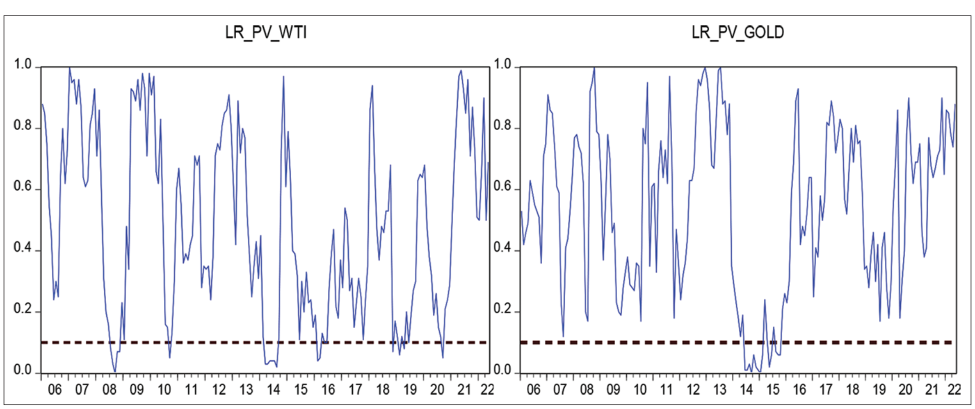
In 2007, the United States encountered a subprime crisis where banks granted loans to agents who were not always solvent. In 2014, we notice two types of causality. The positive causality of oil price on gold is explained by a high oil price due to geopolitical stability. Negative of oil price on gold causality is primarily due to the decline in oil prices due to the refined oil pricing reforms

Table 3: Parameter stability tests

Tests	Statistics	WTI equation	P-value	Statistics	GOLD equation	P-value	Statistics	VAR system	P-value
Sup-F	4.5864		0.9578	20.6738*		0.0087	25040.3167*		0.0000
Ave-F	1.9256		0.9230	7.4624**		0.0526	2084.7957*		0.0000
Exp-F	0.9931		0.9612	6.8926*		0.0097	364.6188*		0.0050
Lc							3.2074*		0.0000
	Statistics	**WTI equation**	**P-value**	**Statistics**	**PLATINUM equation**	**P-value**	**Statistics**	**VAR system**	**P-value**
Sup-F	2.9853		0.9992	25.8155*		0.0009	24636.6034*		0.0000
Ave-F	1.7063		0.9606	10.0100*		0.0092	2099.38817*		0.0000
Exp-F	0.8592		0.9856	8.2171*		0.0026	43.0589*		0.0000
Lc							3.2717*		0.0000
	Statistics	**WTI equation**	**P-value**	**Statistics**	**SILVER equation**	**P-value**	**Statistics**	**VAR system**	**P-value**
Sup-F	5.3941		0.9006	20.7382*		0.0085	2.39902*		0.0000
Ave-F	2.3377		0.8301	11.5955*		0.0029	2.08849*		0.0000
Exp-F	1.2495		0.8901	6.9937*		0.0088	6.6423*		0.0030
Lc							4.8378*		0.0000

*and **denotes the significance at 1% and 5%. *P* values are calculated using 1000 bootstrap repetitions

Figure 2: Bootstrap P-values of LR test statistic testing the null hypothesis that WTI does not Granger cause GOLD and GOLD does not Granger cause WTI



of March 27, 2013. Gold frequently affected oil price during the Coronavirus and recently during the Russian war in Ukraine.

Figures 4 and 5 illustrate the dynamic profile of the value of the bootstrap probability and the direction of the effect of crude oil price (WTI) on platinum and the influence in the opposite direction (platinum on WTI). This figure allows the rejection of the null hypothesis at the 10% level that WTI does not cause platinum in the Granger sense. Indeed the P-values are below the horizontal line dotted in red. The most relevant periods during which the oil price causes platinum in the sense of Granger are the following: 2008M04-2010M12; 2014M04-2014M06; 2015M03-2017M02 and 2020M06-2021M02. However, the periods according to which platinum causes in the sense of Granger the price of oil are as follows: 2010M01-2010M09 and 2014M01-2015M06.

Figures 6 and 7 trace the value of the bootstrap probability as well as the size and directions of the influence of oil on silver and vice versa, namely the impact of silver on oil. This figure highlights that the null hypothesis according to which oil does not cause silver in the Granger sense is rejected at the level of significance of 10% during the following periods: 2010M06-2010M09; 2011M03-2011M05; 2014M02-2014M08 and 2015M06-2016M06. On the other hand, the periods according to which silver causes in the sense of garnering the price of oil are the following: 2014M06-2014M08 and 2014M10-2015M06.

Figure 3: Bootstrap estimation of the sum of the rolling coefficients for the impact of WTI on GOLD and the impact of GOLD on WTI

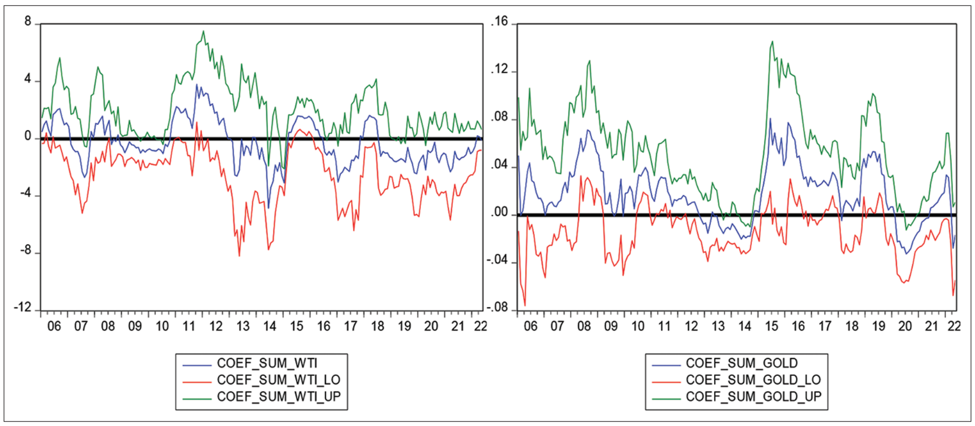


Figure 4: Bootstrap P-values of LR test statistic testing the null hypothesis that WTI does not Granger cause PLATINUM and PLATINUM does not Granger cause WTI

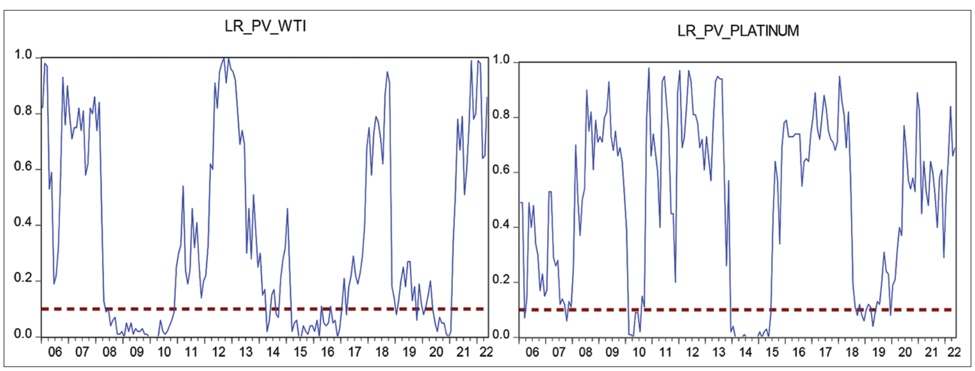


Figure 5: Bootstrap estimation of the sum of the rolling coefficients for the impact of WTI on PLATINUM and the impact of PLATINUM on WTI

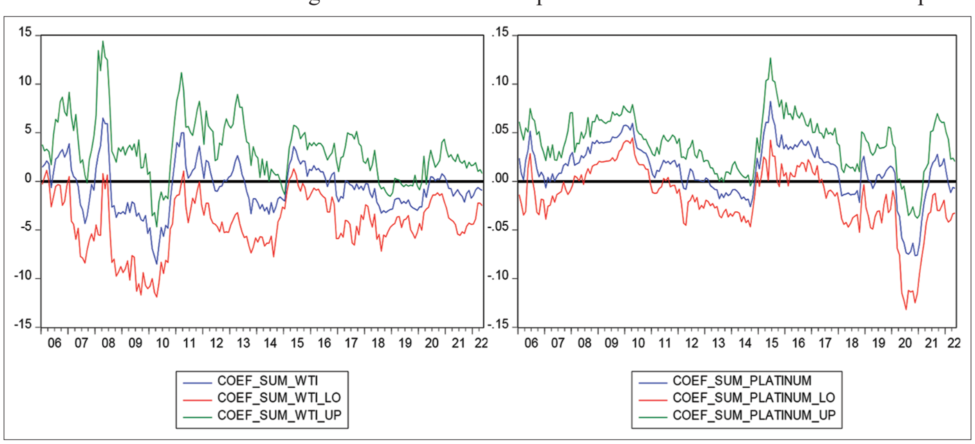


Figure 6: Bootstrap P-values of LR test statistic testing the null hypothesis that WTI does not Granger cause SILVER and SILVER does not Granger cause WTI

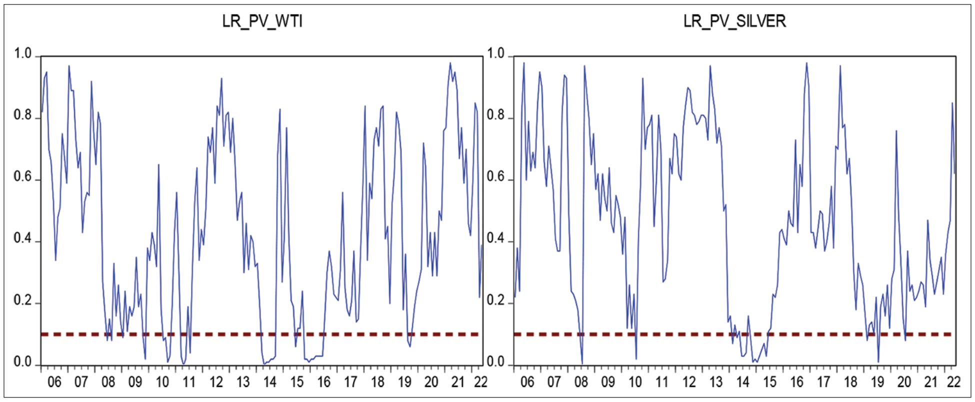
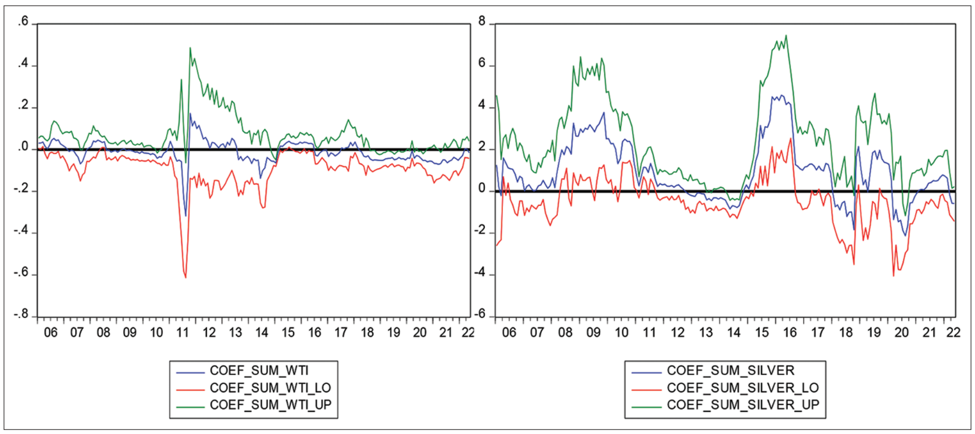


Figure 7: Bootstrap estimation of the sum of the rolling coefficients for the impact of WTI on SILVER and the impact of SILVER on WTI



In 2011, the positive causality of oil prices on silver is explained by the increase in oil prices which encourages producers to increase the volume of their production. The negative causality is explained by the global financial crisis. Silver frequently touches the price of oil during the epidemic and the Ukrainian-Russian war.

These different sub-periods detected coincide with exceptional events such as the global subprime crisis at the end of which the increase in crude oil stimulates oil producers to increase the volume of production and benefit from an additional profit margin. The 2014 crisis is strongly explained by the global economic slowdown caused by the increase in shale oil production in the United States, which contributes to the drop in oil prices. In 2020, and for the 1st time, the WTI is negative. It is around −37.63 dollars per barrel. This sharp decline is at the origin of the Covid-19 health crisis which has caused economic stagnation on an international scale.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The main objective of the study is to analyze the comparative effect of US oil prices (WTI) on precious metals including gold, silver and platinum. Monetary authorities and economic policy makers can therefore monitor the price of major commodities and metals in the markets.

The interaction between the price of oil and the precious metals occupies a particular attention for the policy makers who seek an enabling environment, especially for the strategies of investment. This study is the subject of an empirical modeling based on causalities with bootstrap rolling window estimation allowing studying the nature of causality between WTI and three types of precious metals namely gold, platinum and silver.

The main empirical result from this manuscript reveal the absence of causality between gold, silver and the price of oil, which shows that gold and silver are safe havens for investment. In addition, the presence of a unidirectional causality between the price of American oil and platinum shows that platinum is not a safe haven during times of crisis for investors. Americans buy platinum for investment purposes, jewelry and in particular, platinum is very important for the petrochemical industries. Therefore, during bull markets, rising stock prices cause increased consumption as a result of improved income and earnings for optimistic investors. However, this is not the case for gold and silver where there is an absence of causality between the price of oil (WTI) and gold on the one hand, and between the price of oil and silver on the other part. So gold and silver can be substitutes for oil as a safe haven.

The significant rejection of the null hypothesis of granger causality during various sub-periods such as the 2008 subprime crisis, 2011 sovereign debt crisis, 2014 oil crisis and currently the coronavirus

(COVID-19) epidemic and the Ukraine war -Russia (end of 2021). These various crises are unfavorable for the international economy. Indeed, the strong uncertainty which is at the origin of geopolitical risks and crises has caused a significant increase in the price of oil and precious metals. In addition, the high uncertainty can affect on the one hand, household consumption and the reduction in international trade, thus causing a depreciation of the currency. Economic uncertainty can affect the profit of exporting firms and high oil volatility. Investors adopt speculative strategies in order to contribute to increased volatility and uncertainty. As a result, they buy more stocks today anticipating that the interest rate will rise in the future.

In order to keep the follow-up and the prosperity of the oil market, political decision-makers such as investors must adopt efficient economic strategies such as portfolio diversification which makes it possible to reduce uncertainty and the level of risk. They must also better manage risk in the highly dependent oil market in order to improve the economic performance of the oil industries.

Policy makers use gold an silver as a safe haven tool against currency risk and the collapse of the global financial system. The government uses gold as a reserve to defend the value of the currency. The absence of causality justifies that gold and silver are safe havens (i.e. the use of gold and silver allow a fragility of the financial system).

The question that arises, as an investor, what type of opportunity can we choose? investment in gold or in silver?

They seem appropriate to invest in gold rather than silver because following a high inflation the value of gold in the future remains stable or increases thanks to the quantity of supply which is low.

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