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Precious Metals and Oil Price Dynamics

Abdulrazak Nur Mohamed[1], Idiris Sid Ali Mohamed[2]*

[1]Faculty of Accountancy, Simad University, Mogadishu, Somalia, [2]Graduate of School of Mathematical Sciences, Universiti Sains Malaysia, Penang, Malaysia. *Email: idriis995@gmail.com

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ABSTRACT

The aim of this study is to examine dynamic relationship among the prices of four precious metals (gold, silver, platinum, and palladium), oil price, and the US dollar/euro exchange rate. Recent literature for precious metals (gold, silver, platinum, palladium) and oil depict a lot contradiction results of their nexus in the long and short runs. So that, there is still much to investigate and learn about their relationship between them and with the exchange rate. The monthly data span from January 1990 to October 2021 is utilized, the study applies the co-integration analysis, multivariate Granger causality test and Variance Decomposition (VDC) analysis. The result shows the evidence of a long-run equilibrium relationship but weak feedbacks in the short run. The precious metal markets respond significantly (but temporarily) to a shock in any of the prices of the other metal prices and the exchange rate. Furthermore, we discover some evidence of market overreactions in the palladium and platinum cases as well as in the oil market. The study implies whether there are overreactions and re-adjustments or not, investors may diversify at least a portion of the risk away by investing in precious metals, oil, and the euro.

Keywords: Precious Metal Prices, Oil Prices, Generalized Variance Decompositions
JEL Classifications: C53, O13, P28

1. INTRODUCTION

Commodities that are attractive instruments for investors because of their low correlation such as oil and precious metals provide high protection against inflation, especially during economic crisis (Cagli et al., 2019; Spierdijk and Umar, 2013) and (Liu et al., 2021) found the opposite although they comment that the industrial metals has significant inflation-hedge in the market. The investors, traders, policy-makers, hedgers and producers interested in knowing the situation of crude oil and precious metals (gold, silver, palladium, platinum) because of their increase in prices, uses and movements (Sari et al., 2010). Globally, the strong demand of oil and the diversification uses of the precious metals in a variety of industries have caused the trade of interest of the commodities in the financial markets (Churchill et al., 2019). As (Baruník et al., 2015) chronicled oil and gold are the most actively traded commodities in the world.

Historically, during the Bretton Woods system gold has been used as a store value and medium of exchange and was also held as an investment by the investors and as reserves by the governments. As well as it works as "safe haven" (Baur and McDermott, 2010; Ciner et al., 2013; Ji et al., 2020; Akhtaruzzaman et al., 2021; Wen et al., 2022; Chemkha et al., 2021). Silver has also historically been considered as a store of value and medium of exchange (Churchill et al., 2019; Jain and Ghosh, 2013). Expectation of high inflation and inflationary build up in the environment call on tendencies towards using precious metals as "safe havens" to avoid risk such as gold and silver. Besides the increase use of industrials platinum and palladium have been achieved to substitute the other two metals which have made the prices of these precious metals play catch up against one another (Sari et al., 2010).

Following World War II, oil emerged as a primary energy source, particularly for transportation, complex mechanical systems, manufacturing, and so on. Crude oil price fluctuations are regarded to have impact on inflation (Sek et al., 2015; Mukhtarov et al., 2019; Talha et al., 2021), the economy (Zhang, 2011) and the economic growth (Mukhtarov et al., 2020). Policymakers and financial authorities regarded as a significant mechanism of the global economy and the primary cause of the business cycle (Bildirici and Sonustun, 2018). Thus its volatility causes real locations of labor and capital across sectors, as well as a shift in labor and financial market equilibrium. This uncertainty problem is one of the most significant challenges for economies in their development/growth phases, which are forced to deal with budget constraints by allocating oil alongside other energy sources (Lescaroux and Mignon, 2008; Rentschler, 2013).

For the most past two decades crude oil has been sufficiently low or at least low enough not to upset the policy makers and consumers in oil importing countries. Analysts agree that oil price in the range of $55–$65 per barrel will be the norm for the next 5-10 years because of the strong demand especially by large emerging economies such as China and India and the capacity constraints on the supply side (Baffes, 2007). However, price co-movements of these precious metals and oil led by their demand has been the focus of an increasing literature with some recommending that price co-movements transmit to more reliable information to market participants than consumer prices (Balcilar et al., 2015). In this study we also include the exchange rate because these commodities are denominated in USD currency a lot so it is likely to have an effect the drive of both oil and precious metals. To the best of our knowledge the previous literature focused on just the long and short relationships between gold and silver (Ciner, 2001; Pierdzioch et al., 2015; Pradhan et al., 2020) and with oil and exchange rate (Bildirici and Sonustun, 2018; Kumar, 2017; Malliaris and Malliaris, 2013). The authors focused on four precious metals (gold, silver, platinum, palladium) and oil depict a lot contradiction results of their nexus in long and short runs (Churchill et al., 2019; Jain and Ghosh, 2013; Soytas et al., 2010; Talbi et al., 2020). Thus the first aim of this paper is to determine the effects of precious metals on each other as well as on the oil price and exchange rate. The second objective is to examine the directional relationships between the prices of the major precious metals, oil price, and USD/EUR dollar exchange rate. The paper is organized as follows. Section 2 discusses the existing literature. Section 3 describes the data and the methodology. In Section 4 the empirical results are presented, and the last section concludes.

2. LITERATURE REVIEW

To have a lot about the precious metals, oil and exchange rate, the literature focused on different approaches. However, one of the strands in the related literature of this study is to investigate the relationship between the variables.

(Yahya et al., 2013) employed the Johansen Multivariate Co-integration and Granger-Causality tests for checking a long-run or equilibrium and short-run relationships between oil and gold. In consequence, the variables were not co-integrated nor granger-caused between them. Therefore, it can be concluded that there is no long-run/equilibrium and short-run relationship between the variables. In contrast, (Sari et al., 2010) found out that a weak long-run relationship between the variables and bi-directional short-run relationship. However, (Sari et al., 2010) were analyzing the dynamic relationship between precious metals (gold, silver, palladium, platinum), oil and the exchange rate. They utilized two different methods, Johansen and Juselius (JJ) and bounds testing approach and both methods showed contradicting results. The bounds test results suggest that there is no co-integration among the precious spot precious metals and oil prices and the exchange rate. Likewise JJ results confirm that no evidence of co-integration in the maximum eigenvalue test although the trace test suggested the presence of co-integration.

Investigating the relationship between crude oil and precious metals prices Bildirici and Türkmen (2015) differentiated the long-run relationship between variables from the causality relationship. They used an asymmetric ARDL technique to investigate the log-run relationship and discovered a valid long-run association between the variables. In contrast, they discovered a non-linear VEC model to investigate the causality link. As a result, they identified evidence of synchronization in the examination of feedback dependency between variables. Crude oil and precious metals like gold are critical commodities whose price and volatility have earned a lot of attention. The volatility of strategic commodity prices is critical for economists, politicians, private investors, and financial institutions worldwide (Bildirici and Türkmen, 2015). From 2006 to 2015, according to Jain and Biswal (2016), the DCC-GARCH crude model was used to examine the contemporary time-varying relationships between global gold, crude oil, exchange rates, and the prices of Indian stock market from the perspective of the DCC-GARCH crude model. On the basis of gold and exchange rate factors, their findings suggest that there was a brief period of negative correlation. The relationship between the US dollar-weighted trade and US gold, oil and stock prices, Azar (2015) studied. The author found that the one price law applies to the gold, oil and stock prices of the dollar, indicating the inverse link between the three variables. Since three assets are in US dollars, the three assets should be decreased by the same amount when the US currency increases. Kumar (2017) employed the Granger-Causality test and the ARDL model in modeling the long-term and short-term relationship between the price of oil and gold in India. The asymmetric Granger-Causality model states that there is a strong nonlinear bidirectional cause between oil and gold, and that the NARDL model stipulates that positive oil price shocks are more efficient. Gold prices are thought to be more sensitive to oil prices in the long term, and the relationship between oil and gold prices is not linear. Lucey and Tully (2016) re-estimated Ciner (2001) work whose findings show that gold and silver do not have a long-run stability and broke their relationship in after 1990s whereas the overall findings for Lucey and Tully (2016) imply that the long-run stability relationship between gold and silver is generally strong and convincing.

Bildirici and Sonustun (2018) used Markov Switching AR Model on data from 1973:4 to 2018:2 to see if there is an influence of the price of oil and gold volatility on each other. They discovered that gold has a significant impact on prices, despite the fact that the reserved effect exists. According to Churchill et al. (2019) they used the ARDL model to evaluate the nature of the long-run link and the direction association between the prices of the key precious metals (gold, silver, platinum, palladium), oil prices, and the US/British bound exchange rate from 1880 to 2016. Their results show there is inconclusive co-integration between gold and platinum price for specifically and all precious metal in general and they specified that there is unidirectional causality between the two precious metals as well. A study conducted by (Arif et al., 2019) shows that the change in global oil price increases the return of palladium and platinum by employing the ARDL technique. The study's aim was to know about the effects of oil price on three white precious metals (silver, palladium, platinum). However, the relationship between the oil prices and silver returns show insignificant. On the other hand, (Churchill et al., 2019) employed linear and non-linear parametric techniques to study long-run and short-run dynamics and found out that there is a strong equilibrium relationship between oil precious metals (gold, silver, platinum) and exchange rate and bi-directional short-run relationship between oil-gold and gold-silver. (Sheikh et al., 2020) broke down the study into three sections, pre-economic crisis, post-economic crisis and the complete sample of the time frame between from January 2004 to January 2019. They found out there are a short-run relationship between exchange rate, gold and prices. (Su et al., 2020) examined the Granger-causal relationship in rolling window framework highlighting the importance of capturing the parameter instability to in the gold and silver Granger-causality analysis. (Khan et al., 2021) investigated causal relationship between gold, oil, exchange rate and stock market and found out that the variables have a long-run relationship between them that contrary with the results (Ali et al., 2020; Asaad, 2021) that show inconsistency result between the variables. (Ajmi et al., 2021)investigated interconnectedness and relationship gold, oil and stock prices. The findings show there are bidirectional relationship between stock and oil prices and between gold and stock prices. A study conducted by (Jiang and Chen, 2020) display the dynamic returns between precious metals (gold, silver, copper and aluminum), energy (oil, natural gas and coal) and carbon in the post-COVID world is significantly higher compared to pre-COVID-19 outbreak period.

Using data from 1991 to 2001 on a daily, weekly, and monthly basis, Smith (2002) discovered a shorter-run nexus between the price of gold and the index of stock exchanges. In the course of the inquiry, four gold coins and six stock indexes were evaluated. A second study, conducted by Smith (2002) utilized data from 1991 to 2001, examined the long-and-short term relationship between gold prices and the exchange rate. The data for this study included three gold prices from the London Stock Exchange at 10.30 a.m., 3 p.m., and end-of-day, as well as 18 different stock exchange indices. The researcher discovered that while there is a significant weak and negative correlation between gold and short-term stock prices, there is no major long-term association between gold and stock prices.

Using a VAR model, Ghosh et al. (2004) examined the effects of global inflation, US inflation, global income, the value of the US dollar, and random shocks on gold prices over the time period from 1979 to 1999. It has been revealed that the price of gold is linked to the amount of inflation, interest rates, and the value of the dollar in the United States. Tully and Lucey (2007) constructed an APGARCH model to investigate the impact of macroeconomic shocks on gold spot and futures prices. The findings reveal that the value of the dollar was a significant macroeconomic predictor of the volatility of gold prices across time.

Sjaastad and Scacciavillani (1996) and Sjaastad (2008) conducted separate investigations on separate time frames of data spanning from January 1982 to June 1990 and from January 1991 to June 2004, respectively. The outcome demonstrates that the price of gold and the euro are correlated; that the price of gold and the exchange rate of the US dollar are correlated; and that the price of gold is controlled by euros in the 1980s and that the dollar gradually replaced euros in the 1990s and beyond. A 5-year period of data analysis was used by Malliaris and Malliaris (2013) to examine the relationship between gold, oil, and the euro. They discovered that there was no long-term relationship between any of the three variables.

Gold price and the Australian dollar-US dollar linkage have a significant positive relationship. A 1% increases in the gold price resulting in a 0.5% rise in the AUD/USD exchange rate, according to Haque et al. (2015) research. Vector Auto Regressive (VAR) and the co-integration test were utilized by Nair et al. (2015) to investigate the relationship between the rate of exchange and gold prices in India and found inconclusive results. They asserted that the recession in India, the subsequent USD appreciation, and a tense global financial backdrop damaged and damaged their relationship.

In recent decades, gold and silver, the two most valued precious metals, have been recognized as important financial assets. According to the study, the widespread trading of these precious metals has greatly enhanced their liquidity, boosting their marketability (Frankel, 1987; Lutzenberger et al., 2017; Shammugam et al., 2019).

Data from January 1982 to July 1992 of daily prices of gold and silver relationship of Handy and Harman in New York, Wahab et al. (1994) analyzed. The researchers determined the limited and uncomplicated spreads of gold and silver to determine the inter-temporal behavior and the predictability of the so-called gold-and-silver price dispersion. There is not only a relationship between price changes for the gold silver spread, but price shocks seem to have more effect on the market than price shocks for both constrained and restricted gold silver prices on future markets price shocks.

Escribano and Granger (1998) investigated at gold and silver prices to determine whether there was any indication of a semi-stable or stable connection that might be used to forecast the prices of silver and gold. The researchers divided the analysis into 3 time periods: Full example (December 1972 to June 1990), post-bubble period (April 1981 to June 1990), and post-example period (July 1990 to June 1994) to examine the effects of a significant air pocket on the previously run relationship and assess how much non-direct blunder revision model (NECM) can account for the rest. Their findings indicate that co-integration could have occurred at some point, particularly during the boom and post-bubble periods for monthly data from 1981 to 1990. The stability of the hypothesized relationship is examined using observations from July 1990 to June 1994 through an out-sample estimation experiment. They claim that gold and silver's interdependence has diminished since 1990, showing that the two markets are becoming more different.

In the Tokyo Commodity Exchange (TOCOM) from 1992 to 1998 data set were investigated by Ciner (2001) in the long-term relationship between gold and silver prices. His statistically significant findings show that these two precious metals do not have long-run stability, that in the 1990s the relationship among them broke, and that nowadays they have their own independent markets because they are seen as serving various economic tasks. The author offers a contrast finding to Escribano and Granger (1998) suggesting that the dependence of gold and silver is growing less after the 1990s but is not totally severed. This finding, however, has been challenged by work using a different technique, JJ, and added more data from 1978 to 2002 to the system. Their overall conclusions imply the long-term stability of the relationship between gold and silver. This relationship is generally strong and convincing. However, there are crucial times when it is weakened or seriously damaged.

The price of platinum is most often caused by price changes of other valuable metals, especially gold (Soytas et al., 2010). The fact that greater industrial usage of precious metals resulted in the substitution of close metal cousins such as platinum and palladium, causing the prices of these precious metals to match one another, appears to be going the way of gold and platinum recently (Soytas et al., 2010). However, many scholars have not focused on investigating the relationship between the price of platinum and gold.

Soytas et al. (2010) used the JJ and Bounds testing methods to study the long-run association between spot prices of precious metals (gold, silver, platinum, and palladium), oil, and the USD/euro exchange rate from 04/Jan/1999 to 19/Oct/2007. Both methodologies used suggest that there is no co-integration between variables. Although by using the error variance decomposition (EVC) model, they discovered that the gold price had an impact on the platinum price.

Daily data from January 02, 2009 to December 30, 2011 utilized to examining the presence of a long-term relationship and Granger causality between the world price of oil and precious metals, gold, silver, platinum and palladium (Jain and Ghosh, 2013). For co-integration among variables, they have used ARDL bound test approach. They found that co-integration is only present when the dependent variables are the exchange rate and gold prices in critical value at 5% level of significant and they also specified that this is only true while both cases no trend exists. However, there is no long-run relationship when other variables have been taken as the dependent. Therefore, co-integration exists between the gold and platinum prices.

Investigating the relationship between crude oil and precious metals prices Bildirici and Türkmen (2015) differentiated the long-run relationship between variables from the causality relationship. They used an asymmetric ARDL technique to investigate the log-run relationship and discovered a valid long-run association between the variables. In contrast, they discovered a non-linear VEC model to investigate the causality link. As a result, they identified evidence of synchronization in the examination of feedback dependency between variables. The relationship between the gold and crude oil markets was explored by Zhang and Wei (2010) for daily data between January 04, 2000 and March 31, 2008, and the unidirectional causal effects on petrol to gas were strongly combined.

Azar (2015) analyze a monthly data starts from 1985 to 2014 to investigate the linkage between US stocks, gold and oil with the foreign exchange rate denominated in US dollars. The result of the author displays the impact of change the price of oil on gold is significantly positive. Malliaris and Malliaris (2013) investigated whether a stable long-run relationship exist among three variables include gold and oil price using a daily spot price over a period starts from January 04, 2000 to December 31, 2007. They found that there were not stable equilibrium long-run relations between the variables.

From 1994 through 2011, Le and Chang (2012) used the VAR technique to predict the effect of oil prices on gold. According to the data, oil price shocks have a positive effect on gold prices, meaning that oil price volatility is used to forecast gold price changes. Lee et al. (2012) investigated the nonlinear and causal relationship between gold prices and West Texas Intermediate crude oil prices from 1995 to 2008. The findings of their investigation revealed an uneven long-run relationship between the price of oil and gold prices.

By analyzing annual data from 1960 to 2005 Baffes (2007) analyses the passage in crude oil prices to 35 other goods, including gold and silver. He anticipates that after inflation is taken into account, the passage of precious metals is rather significant. As oil may be seen in the production functions of other commodities or an alternative that includes the criteria for replacement ability, the Granger causality can be considered an economic connection. The economic link between oil prices, gold and silver is apparently quite strong. He finds that price of precious metals in general react heavily to the price of crude oil. Shafiee and Topal (2010) show evidence for correlations between gold, oil, and inflation. Their findings show that the ratio of gold and oil prices has remained steady over a lengthy period of time, indicating a stable relationship. Soytas et al. (2010) offered evidence of short-term correlations between oil, precious metals, and exchange rates. Their research discovered no indication of a long-term relationship between these characteristics.

3. METHODOLOGY

We utilized monthly data series for the precious metals (gold, silver, palladium and platinum) price, crude oil price and USD/EUR exchange rate. The value of US dollar to one EUR is measured in the exchange rate (EXR). The price of crude oil (OIL) is for the benchmark West Texas Intermediate (WTI) and is valued in USD a barrel. The gold (GL) is a fixed price traded the London Bullion Market Association (LBMA) which is expressed in US dollar per troy ounce. Likewise the silver (SL) is measured in US dollar spot price per troy ounce traded in LBMA where the palladium (PL) and platinum (PT) from London Metal Exchange (LME) in US dollar per troy ounce. The analysis include the oil price band in 2000 imposed by Organization of the Petroleum Exporting Countries (OPEC), the 2003 Iraq war, 2007-2008 global financial crises and the economic recession caused by COVID-19 pandemic. We analyze a monthly data span from January 1990 to October 2021. The natural logarithm is used all the series in the analysis.

The logged descriptive statistics presented in Table 1 the variations of coefficients show that the highest varied commodities among the variables is the poor precious metal which is palladium and the gold which is contrary the consistent with the fact that gold has a monetary component that makes a reduction of its demand. In this study, platinum has the lowest volatility amongst the commodities. As Table 2 indicates that was expected, gold and silver prices have the highest positive correlation in the commodity. Both metals have common uses in jewelry and monetary system that make the association between them. According to the oil with the precious metals, platinum has the highest positive correlation with the oil showing the importance of their uses in industrial. The smallest association between the variables is the palladium reflecting it has the lowest positive correlation with all other variables under the analysis including its related pair metal (platinum) which they are common with the industrial use.

Methodologically, we utilize Granger-causality test proposed by (Granger, 1969) which is the most influential work on causality and led to the invention of the term Granger-causality. The Granger-causality is performed to see if 1 time series may forecast others. To put it another way, if two or more variables, x and y exist and x significantly predicted y, then x is the cause and y is the effect on the adjustment path. Next, the Impulse Response, Forecast Error Variance Decomposition (VDC) then is employed to investigate the changes between the variables. Variance decomposition is employed to show how much of the variable of a variable can explained by the innovation to another variable in the same system of simultaneous equation known as Vector Autoregressive (VAR) model when the VAR is assumed that there is no deterministic components. The representation series in levels of a VAR, one can write.

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_l y_{t-l} + \varepsilon_t \quad (1)$$

Where y_t represents a $(n \times 1)$ vector of a commodity, β is $(n \times n)$ matrix of coefficients. In a general format this relationship can be represented as Vector Error Correction (VECM) and it is formulated as:

$$\Delta y_t = \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \ldots + \delta_{l-1} \Delta y_{t-l+1} + \prod \Delta y_{t-l} + \varepsilon_t \quad (2)$$

$$\delta_i = \sum_{i=1}^{l-1} -\beta_i ; \ldots \prod = I_n + \delta_{l-i}$$

3.1. The Co-integration Test

The co-integration testing is used to assess the long-term relationship among variables. (Engle and Granger, 1987) introduced the Co-integration theory, which asserts that non-stationary variables can be linearly combined to become stationary variables, implying that these variables have a co-integration relationship. These variables have long-term stable relationships, and the following two statistics were utilized to test the number of co-integration vector groups. The first method is joint trace test which its test statistic was:

$$\lambda_{trace}(r) = -n \sum_{i=r+1}^{m} \ln(1 - \hat{\lambda}_t) \quad (3)$$

The test is conducted sequentially and under the null at most $r = 0.1, \ldots m-1$ co-integrating vectors such that:

Table 1: Descriptive statistics in log form

	LGL	LSL	LPL	LPT	LOIL	LEXR
Mean	6.695	2.532	6.319	6.876	3.967312	3.258345
Median	7.022	2.712	6.393	6.875	4.056034	3.286093
SD	0.658	0.639	0.695	0.411	0.532598	0.163958
Skewness	−0.508	−0.348	0.335	−0.495	−0.474022	−0.541795
Kurtosis	1.723	1.940	2.568	2.718	2.522682	2.957645
Jarque-Bera	30.411	18.367	7.283	12.124	12.86226	13.42557
Probability	0.000	0.000	0.026	0.002	0.001611	0.001215
Observations	274	274	274	274	274	274

Source: Prepared by the authors (2023)

Table 2: Correlation

	LGL	LSL	LPL	LPT	LOIL	LEXR
LGL	1.000000					
LSL	0.960	1.000000				
LPL	0.640	0.559	1.000000			
LPT	0.741	0.833	0.170	1.000000		
LOIL	0.746	0.827	0.254	0.928	1.000000	
LEXR	0.690	0.687	0.270	0.655	0.699	1.000000

Source: Prepared by the authors (2023)

H_0: $r = 0$ versus H_1: $r > 0$ H_0: $r \leq 1$ versus H_1: $r > 1$ H_0: $r=m-1$ versus H_1: $r = m$

H_0: $r(\prod) \leq m$ a maximum of r co-integration vector groups, H_1: $r(\prod) > m$ where $\prod$ symbolised the number of groups of independent vector-matrices, i.e. the number of Eigen values that varied from 0; n denoted the number of samples; r denoted the number of co-integrated vector groups; $\hat{\lambda}_t$ denoted the estimated value of the i_{th} Eigen value; and m denoted the resultant number of Eigen values that obeyed the 2 distribution and were under investigation.

The second method is Maximum Eigenvalue Test. The regression statistics is formulated as:

$$\lambda_{max}\left(r, r+1\right) = -n\ln(1-\hat{\lambda}_{r+1}) \quad (4)$$

The test is conducted sequentially and under the null at most r = 0,1,…m–1 co-integrating vectors such that:

H_0: $r = 0$ versus H_1: $r = 1$ H_0: $r = 1$ versus H_1: $r = 2H_0$: $r = m-1$ versus H_1: $r = m$

H_0: $r(\prod) = m$ and there were m groups of co-integration vectors, H_1: $r(\prod) = m + 1$. Where n denoted the sample number; m represented the number of groups of co-integrated vectors and $\hat{\lambda}_t$ was the estimated value of the t^{th} Eigen value that obeyed the Chi-square distribution and that were under examination. Fir this study we employ the method developed by (Johansen, 1991) and (Johamen and Jtiselius, 1990) abbreviated (JJ). The important advantage of JJ approach is that it can be applied I(2) or higher order series as long as the series are having same order of integration. Since our variables are stationary for the first difference we can apply JJ to test for con-integration of the variables.

3.2. Granger-Causality Test

The progress of Granger-causality is primarily due to the data-driven methodology's ability to allow analysts to find directional effects of variables without previous knowledge of the subject matter because if two or more variables are co-integrated, then there must be Granger-causality (either in the short-term or long-term or both) between them-either one-way or in both directions although the contrast is not true, when the series are not co-integrated. As a result, the vector error correction model (VECM) plays a significant

Table 3: Unit root test

Variable	Type	ADF		KPSS		PP	
		Level	1st difference	Level	1st difference	Level	1st difference
LGOLD	Intercept	−1.031	−14.464[a]	1.691	0.202[a]	−1.027	−14.397[a]
	Trend and intercept	−0.972	−14.461[a]	0.376	0.132[a]	−1.090	−14.393[a]
LSL	Intercept	−1.247	−13.012[a]	1.374	0.145[a]	−1.162	−13.012[a]
	Trend and intercept	−1.726	−12.991[a]	0.344	0.106[a]	−1.498	−12.991[a]
LPL	Intercept	−0.857	−11.917[a]	1.305	0.098[a]	−0.843	−11.881[a]
	Trend and intercept	−2.164	−11.931[a]	0.249	0.038[a]	−2.055	−11.887[a]
LPT	Intercept	−2.940	−12.266[a]	0.814	0.276[a]	−2.472	−12.266[a]
	Trend and intercept	−2.146	−12.341[a]	0.447	0.059[a]	−1.946	−12.320[a]
LOIL	Intercept	−3.198	−11.814[a]	0.886	0.164[a]	−2.886	−11.359[a]
	Trend and intercept	−3.205	−11.843[a]	0.393	0.051[a]	−2.781	−11.350[a]
LEXR	Intercept	−1.851	−5.285[a]	0.893	0.037[a]	−4.958	−38.835[a]
	Trend and intercept	−2.559	−5.270[a]	0.246	0.036[a]	−7.119	−38.750[a]

[a]Symbol shows the three tests ADF, KPSS and PP are significant at 5% level at first difference of the variables. SLS, LPL and LPT are the log of silver, palladium and platinum, respectively

Table 4: Co-integration

Unrestricted Co-integration rank test (Trace)				
Hypothesized No. of CE (s)	Eigenvalue	Trace statistic	0.05 Critical value	Prob.**
None*	0.166165	120.3419	95.75366	0.0004
At most 1*	0.115759	71.45913	69.81889	0.0368
At most 2	0.054812	38.36525	47.85613	0.2863
At most 3	0.047701	23.20142	29.79707	0.2363
At most 4	0.034688	10.05372	15.49471	0.2766
At most 5	0.002068	0.556881	3.841466	0.4555
Unrestricted Co-integration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE (s)	**Eigenvalue**	**Max-Eigen statistic**	**0.05 Critical value**	**Prob.****
None*	0.166165	48.88273	40.07757	0.0040
At most 1	0.115759	33.09388	33.87687	0.0618
At most 2	0.054812	15.16383	27.58434	0.7352
At most 3	0.047701	13.14769	21.13162	0.4388
At most 4	0.034688	9.496839	14.26460	0.2471
At most 5	0.002068	0.556881	3.841466	0.4555

Source: Prepared by the authors (2023)

Table 5: Forecast error variance decomposition

Variance decomposition of LGOLD							
Period	S.E.	LGOLD	LSL	LPL	LPT	LOIL	LEXR
1	0.037	100.000	0.000	0.000	0.000	0.000	0.000
2	0.057	99.792	0.086	0.058	0.013	0.017	0.031
3	0.069	99.603	0.269	0.050	0.010	0.031	0.034
4	0.080	99.581	0.219	0.037	0.013	0.085	0.061
5	0.091	99.187	0.234	0.042	0.268	0.067	0.199
6	0.102	98.705	0.269	0.064	0.684	0.066	0.209
7	0.110	98.195	0.264	0.104	1.129	0.059	0.246
8	0.119	97.780	0.287	0.120	1.464	0.053	0.293
9	0.126	97.458	0.327	0.137	1.676	0.076	0.323
10	0.133	97.226	0.351	0.158	1.788	0.112	0.362
Variance decomposition of LSL							
1	0.063	54.350	45.649	0.000	0.000	0.000	0.000
2	0.100	51.3154	47.797	0.372	0.200	0.000	0.314
3	0.126	49.665	48.230	0.615	1.215	0.003	0.269
4	0.147	49.907	47.110	0.608	2.158	0.009	0.205
5	0.167	53.358	44.276	0.490	1.682	0.027	0.164
6	0.186	56.193	41.636	0.471	1.474	0.087	0.137
7	0.203	57.911	39.887	0.480	1.413	0.179	0.127
8	0.217	59.285	38.438	0.509	1.377	0.226	0.163
9	0.230	60.339	37.363	0.513	1.377	0.204	0.202
10	0.242	61.228	36.488	0.511	1.350	0.184	0.235
Variance decomposition of LPL							
1	0.076	10.569	10.281	79.148	0.000	0.000	0.000
2	0.125	10.134	11.651	78.108	0.072	0.002	0.030
3	0.161	9.834	15.061	74.673	0.084	0.326	0.019
4	0.191	8.917	18.447	71.787	0.152	0.666	0.029
5	0.220	10.714	19.114	69.044	0.118	0.954	0.053
6	0.247	12.755	19.455	66.419	0.281	1.010	0.076
7	0.270	13.988	20.496	63.575	0.789	1.022	0.127
8	0.291	14.719	21.584	61.076	1.461	0.998	0.159
9	0.309	15.350	22.421	58.831	2.309	0.901	0.185
10	0.326	15.893	23.219	56.633	3.210	0.811	0.230
Variance decomposition of PLT							
1	0.053	29.424	10.242	11.305	49.027	0.000	0.000
2	0.085	30.606	12.275	9.344	47.317	0.001	0.454
3	0.111	29.265	12.914	8.574	48.619	0.108	0.517
4	0.132	28.420	14.227	7.789	48.497	0.415	0.649
5	0.151	31.758	14.144	7.313	44.903	1.199	0.679
6	0.166	35.089	14.323	7.048	41.159	1.661	0.717
7	0.178	37.703	14.955	6.591	38.090	1.867	0.792
8	0.188	39.782	15.729	6.125	35.658	1.873	0.830
9	0.196	41.553	16.490	5.674	33.640	1.747	0.893
10	0.204	42.979	17.283	5.254	31.874	1.615	0.992
Variance decomposition of LOIL							
1	0.085	0.478	10.516	0.148	5.372	83.484	0.000
2	0.140	1.633	13.543	0.0778	11.989	72.202	0.552
3	0.179	1.695	16.000	0.175	17.639	63.110	1.377
4	0.208	2.276	18.895	0.201	20.850	55.760	2.015
5	0.233	4.330	21.261	0.164	22.655	49.120	2.468
6	0.255	6.371	23.214	0.138	22.656	44.899	2.719
7	0.275	7.603	24.926	0.136	21.972	42.442	2.917
8	0.293	8.324	26.327	0.224	20.834	41.218	3.069
9	0.310	8.950	27.275	0.397	19.460	40.726	3.188
10	0.327	9.364	27.985	0.653	18.040	40.619	3.335
Variance decomposition of LEXR							
1	0.066	0.321	0.011	1.330	0.024	1.288	97.023
2	0.070	2.102	1.173	1.808	1.504	1.485	91.925
3	0.080	3.003	1.355	2.369	2.780	1.768	88.722
4	0.093	3.692	1.067	3.111	4.534	2.160	85.434
5	0.099	4.952	1.713	2.832	7.980	2.114	80.406
6	0.109	5.711	1.513	2.701	8.087	1.897	80.087
7	0.115	6.717	1.497	2.529	9.279	1.732	78.244
8	0.121	7.300	1.604	2.343	10.232	1.585	76.933
9	0.128	8.016	1.462	2.211	10.301	1.432	76.576
10	0.132	8.605	1.457	2.088	10.921	1.358	75.568

Source: Prepared by the authors (2023)

role in identifying the endogeneity or exogeneity of the variables in the model. Therefore, the VECM is employed to ascertain the direction of the causal effects in the system given that the co-integration tests do not imply the direction of Granger causality. The regression model of Granger-causality was formulated as:

$$x_t = \alpha_0 + \sum_{i=1}^{p} \omega_i x_{t-i} + \sum_{j=1}^{q} \varphi_j y_{t-j} + e_t \quad (5)$$

$$y_t = \beta_0 + \sum_{i=1}^{p} \delta_i x_{t-i} + \sum_{j=1}^{q} \eta_j y_{t-j} + v_t \quad (6)$$

Variable x lead variable y if the results showed that only the null hypothesis was rejected. However, a causal relationship between x and y exists if both null hypotheses H_0 and H_1 were rejected. Although it has been used widely, there are some drawbacks proposed in the literature. Thus we also utilize (Toda and Yamamoto, 1995) as expansion which improves as the power of Granger-causality test (Doran and Rambaldi, 1997) and have since been applied in economics especially to analyze causalities between macroeconomic factors and commodity prices (i.e. Jain and Ghosh, 2013; Klotz et al., 2014).

4. RESULTS AND DISCUSSION

Before testing for the presence of co-integration, we test unit roots of the variables to determine their order of integration (I) and the corresponding maximum order of integration (m) of the pair of variables. For this we employ (Dickey and Fuller, 1979) and (Phillips and Perron, 1988). However, these two common tests there are some weaknesses reported in the literature so in this analysis we also utilize (Kwiatkowski et al., 1992) unit root test for further checking.

Table 3 reports the results of the unit root tests. All tests indicate that the variables are I(1). The JJ results in Table 4 indicate the presence of co-integration both Trace and Maximum Eigenvalue statistics. Thus, we utilize the data series in the VECM to estimate the generalized-forecast error variance decompositions.

Table 5 reports the Forecast Error Variance Decomposition of the variables. The results certainly reflect that most variations of precious metals (gold, silver, palladium, platinum), oil price and exchange rate are due to their own shocks. However, gold and exchange rate has the most variations of their own innovation in the system. Among precious metals, there is no bidirectional relationship between the metals and the oil. Metals and oil price changes with the exchange rate do not explain the variation of the gold price. The reverse relationship between other metals, oil and gold is somewhat stronger as gold explains higher value of their prices. According to all precious metals platinum has the highest effect on gold. There is no evidence of bidirectional relationship between these four precious metals although they affect gold which behaves as a safe haven and a hedge against inflation.

The impact of oil on gold and silver is lower than the impact they have on the oil because gold is a reserve currency, a safe haven and the number one choice for jewelry as well as silver is considered recently by the investors. So gold and silver have strong impact price change of oil. However, the effect on the other side, the other

Table 6: Dependent variable: D (DLGOLD)

Excluded	Chi-sq	df	Prob.
D (DLSILVER)	3.310280	2	0.1911
D (DLPALLADIUM)	2.401071	2	0.3010
D (DPLATINUM)	0.567848	2	0.7528
D (DLOIL)	2.399609	2	0.3013
D (DLEXR)	0.692625	2	0.7073
Dependent variable: D (DLSILVER)			
D (DLGOLD)	2.282447	2	0.3194
D (DLPALLADIUM)	1.095248	2	0.5783
D (DPLATINUM)	2.098102	2	0.3503
D (DLOIL)	0.515754	2	0.7727
D (DLEXR)	0.325612	2	0.8498
Dependent variable: D (DLPALLADIUM)			
D (DLGOLD)	2.793878	2	0.2474
D (DLSILVER)	1.945470	2	0.3780
D (DPLATINUM)	4.673189	2	0.0967
D (DLOIL)	4.468657	2	0.1071
D (DLEXR)	2.264364	2	0.3223
Dependent variable: D (DPLATINUM)			
D (DLGOLD)	1.143792	2	0.5645
D (DLSILVER)	1.568044	2	0.4566
D (DLPALLADIUM)	1.886249	2	0.3894
D (DLOIL)	4.097747	2	0.1289
D (DLEXR)	1.869882	2	0.3926
Dependent variable: D (DLOIL)			
D (DLGOLD)	3.474978	2	0.1760
D (DLSILVER)	0.840318	2	0.6569
D (DLPALLADIUM)	17.37329	2	0.0002
D (DPLATINUM)	13.66573	2	0.0011
D (DLEXR)	30.58557	2	0.0000
Dependent variable: D (DLEXR)			
D (DLGOLD)	6.423613	2	0.0403
D (DLSILVER)	4.281671	2	0.1176
D (DLPALLADIUM)	4.308247	2	0.1160
D (DPLATINUM)	2.115286	2	0.3473
D (DLOIL)	27.30212	2	0.0000

Source: Prepared by the authors (2023)

two cousin precious metals-palladium and platinum is high. The effect of platinum on the oil is higher than the palladium because oil and platinum have common uses in the market such as industrial uses. The exchange rate impacts 36.2%. Silver and palladium are affected by the exchange a value of 23.5% and 23%, respectively where the platinum is 99.2% affected. Overall the exchange rate has the highest impact on oil.

Short term Granger causality relationship can be observed through Exogeneity Wald test. Based on Table 6 results it indicates that there is a bidirectional short-run relationship between the price of oil and the exchange rate. The result show that the palladium and the platinum have a causal effect on oil rather than the other two precious metal (gold and silver) this is because of their use in the industrial. Between the precious metals, just the cousin metals (palladium and platinum) has one way causal effect on the other. The result display the palladium effect the platinum in the short-run. The causal effect between the exchange rate and the precious metals, it indicate the gold has effect on the exchange rate.

5. CONCLUSION

This paper investigates the relationships between precious metals (gold, silver, palladium and platinum) price, crude oil price and

USD/EUR exchange rate. The latter is expected to be the link that relates all these industrial commodities because they are priced in the US dollar. The dollar/euro exchange rate is chosen because those two major currencies are interchangeably used in active portfolios that include precious metals and oil. We find that there is long-run equilibrium relationships between those prices in the exchange rate. It may imply that those commodities may be sensitive to common macroeconomic factors in the long run.

Likewise, there is evidence that precious metals' prices and exchange rate only the gold may be closely linked in the short run. Henceforth, traders may benefit in the short run from the information content of an innovation in one spot market over the others in this regard. This is what has happened in the gold, silver, palladium and platinum and foreign exchange markets recently (Sari et al., 2010).

For precious metal traders, the results confirm the prevailing view that the rich and poor metals, platinum and palladium, are close industrial relatives because the former plays catch up to the latter, while gold and silver are their distant cousins. Platinum and palladium have information content to each other equivalent to the content between the rich and close relatives, gold and silver. This implies that under normal conditions the currently laggard palladium will continue playing catch up with platinum in a continuing or new bull commodity market as it is increasingly being sought in the same industries that demand platinum. Precious metal traders should consider a pick up in platinum prices as a precursor for an ensuing rise in the palladium price in a short period of time. For mineral traders in general, shocks in the precious metals and oil markets have positive impact on poor precious metals (palladium, platinum). These results support the efficiency of the markets.

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