Resources Policy 79 (2022) 102939

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

# Impact of the COVID-19 pandemic on return and risk transmission between oil and precious metals: Evidence from DCC-GARCH model

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ARTICLE INFO

*Keywords:*
The COVID-19
Precious metals
Oil
DCC-GARCH

ABSTRACT

It is frequently discussed in the literature that the correlation between low-correlation assets under ordinary market conditions may increase during crisis periods. To contribute to the ongoing debates, this paper empirically examines risk transmission between oil and precious metal markets induced by the COVID-19 pandemic using the DCC-GARCH model. The findings reveal evidence of a significant risk transmission between oil prices and precious metal prices, particularly during the onset of the COVID-19 pandemic. The findings point out that the negative relationship between oil and all precious metals returns in the pre-COVID-19 period has changed with the effect of the pandemic. In this process, it is revealed that the negative relationship between oil and gold has strengthened, but the negative relationship between oil and silver has weakened. In addition, the correlations between oil and platinum and palladium turn positive. The empirical findings imply that investors and portfolio managers seeking portfolio diversification and hedging opportunities in a high-risk environment such as the COVID-19 pandemic should consider gold and silver assets for investment.

## 1. Introduction

The COVID-19 global epidemic, which has become the only agenda of the whole world, has also completely affected the financial markets (Adekoya et al., 2021; Baek and Lee, 2021; Mensi et al., 2021; Salisu et al., 2021; Yousaf, 2021). The decline in production and consumption as well as supply chain due to social isolation creates negative pressure on the cash flows of companies operating in many sectors. The uncertainty and risk perception created by the epidemic cause volatility in financial markets and commodity prices. The uncertainty and risk perception created by the epidemic cause volatility in financial markets and commodity prices (Barro et al., 2020). The pandemic puts additional downward pressure on commodity prices, especially oil, as it causes a sharp drop in demand. For this reason, companies need to proactively take decisive steps within the scope of alternative investment policies and changes in corporate behavior that increase resilience against both operational and financial difficulties.

In this pandemic environment, investors and portfolio managers choose more than one investment instrument to reduce investment risks or to benefit from the returns of different investment instruments (Yildirim et al., 2020). Investors want to know the reaction of investment instruments to risk factors when choosing investment instruments to keep in their portfolios. To reduce the risk in portfolios, instruments that react differently to market events are primarily preferred. In portfolio management, knowing the reaction of the instruments to macroeconomic variables while choosing investment instruments may increase the level of success. One of the most important issues to be considered within the framework of the diversification principle in portfolio management is whether the volatility movement experienced in any market spreads to other markets. While the high integration among financial markets around the world allows for the acceleration of capital flows, on the other hand, the contagion of financial problems increases in global crises such as the COVID-19 pandemic (Barro et al., 2020). The volatility spillover and the interaction among financial markets can significantly influence investors and portfolio managers' investment strategies and financial decision-making processes. In addition, investors consider volatility and its impact on international markets to predict the returns of financial assets (Degirmenci and Abdioglu, 2017). Therefore, determining both volatility and the volatility spillover between markets is a very critical point in terms of estimating financial asset returns. It is essential for portfolio managers to investigate more carefully whether a shock in one market affects the volatility in other markets during this

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https://doi.org/10.1016/j.resourpol.2022.102939
Received 12 September 2021; Received in revised form 2 August 2022; Accepted 3 August 2022
Available online 18 August 2022

pandemic process.

However, it is observed that the correlation among the low-correlation assets, which are taken into the portfolio for diversification in ordinary market conditions, increases in crisis periods and an adequate diversification benefit cannot be achieved (Diebold and Yılmaz, 2009; Baur and Lucey, 2010; AlKulaib and Almudhaf, 2012; Diebold and Yilmaz, 2012; Barro et al., 2020). Investors and portfolio managers whose risk appetite decreases due to the increase in volatility and uncertainties in financial markets during crisis periods tend to sell off all kinds of risky assets, and this tendency may cause an increase in the correlation among assets (Baur and McDermott, 2010; Deniz et al., 2018). Investment portfolios may shift from risky assets to safe havens in order to strengthen portfolio returns and optimize risk parameters when risks and/or uncertainty in the markets increase.

In this case, one of the main issues that investors need to decide on portfolio management is the selection of investment instruments to include in the portfolio. Stocks, bonds and precious metals are among the main investment instruments. Nowadays, the oil is also seen as important asset for investors, since energy products are among the main expenditures of both households and companies. For this reason, oil and precious metals are among the most strategic commodities subject to production, consumption and foreign trade in global markets, and therefore, they are closely monitored by investors as risk management tools to diversify and hedge portfolios against risks in financial markets (Ciner et al., 2013; Alkhazali and Zoubi, 2020; Trabelsi et al., 2021). Precious metals, which are seen as a safe haven, since they have a negative correlation with other alternative financial assets such as stocks and bonds in times of extreme volatility in the financial markets, such as the pandemic, are widely preferred for hedging and portfolio diversification. The background to this idea is that precious metals have more stable price movements than alternative assets. Unlike other assets such as stocks, precious metals are also used as inputs in production in price formation.

As the largest traded commodity, oil is an important production input and natural resource for both importing and exporting countries. Therefore, increases and fluctuations in oil prices can cause serious production losses. Oil prices are one of the assets most affected by international shocks. Volatility in oil prices can cause both individual and global economic downturns (Erdoğan et al., 2020; Yildirim et al., 2018). The mutual interaction of oil, which is one of the strategic commodities, with economic activities causes investors to evaluate oil as an investment asset. For this reason, economic units also take oil prices into account when making investment decisions.

The basis of entry into financial markets is the expectation of return. The expected return varies depending on the risk preference of the related one (Yildirim, 2021). However, studies reveal that anxiety caused by negative shocks changes investors' willingness to take risks (Loewenstein, 2000; Knutson et al., 2008; Guiso et al., 2018; Barro et al., 2020). The effects of investors' risk appetites on financial markets are also a subject emphasized in the literature. Existing literature shows that a significant portion of global asset returns can be explained by global risk aversion (Hacihasanoglu et al., 2012; Miranda-Agrippino and Rey, 2015; Demirer et al., 2018; Xu, 2019). In general, there are many approaches to the relationship between financial data and strategic commodities. This paper aims to examine the risk transfer link between strategic commodities such as oil and precious metals with the DCC-GARCH (DCC hereafter) test approach, covering period between January 1, 2019, and April 14, 2021, which includes the ongoing COVID-19 pandemic period. In this context, examining the risk spillover among strategic commodity markets will guide investors in the decision-making processes. On the other hand, it will provide useful information to policy makers at the point of policy making.

To this end, this paper contributes to the existing literature in three aspects. First, it is of great importance that the risk and return level of each financial asset, as well as the risk transfers among assets, can be determined accurately, in terms of investors' preferences and rational decision-making. It is seen that most of the studies in the literature on the relationship between oil prices and precious metals investigate the relationship between commodity prices or the spillover effect between these prices. However, there are very limited studies on the risk spillover between oil and metal prices in the literature. Actually, oil price risk in the long run can boost metal price risk. Secondly, it is frequently referred to in the literature that volatility in financial markets can increase sharply during crisis periods, leading to interconnectedness, and that the correlation between financial assets with low correlations in ordinary market conditions increases during crisis periods. In this study, the COVID-19 period is chosen as an indicator of a crisis period because the majority of commodity markets were adversely affected by the COVID-19 pandemic. In this respect, the paper expands the extant literature by examining the risk transfer between oil prices and precious metals returns before and during the COVID-19 crisis. To the author's knowledge, this is the first paper to comprehensively examine the risk and return transmission between the oil market and precious metals markets in a normal and high-risk environment such as the COVID-19 pandemic, and to provide guiding points to investors in the decision-making process depending on the market situation. Third, it deals with the innovative model adopted in the study. Correlations between the return, risk and volatility of commodity assets are among the main factors in determining optimal investment strategies, especially for hedging purposes. At this point, univariate volatility models are insufficient to analyze the time-varying relationships between assets, and thus multivariate GARCH models, which are needed for more detailed analyzes in financial applications, are developed. One of these methods is the DCC (Dynamic Conditional Correlation) GARCH model developed by Tse and Tsui (2002) and Engle (2002) using the CCC (Constant Conditional Correlation GARCH model) proposed by Bollerslev (1990) to model the multivariate GARCH structure. The DCC-GARCH model allows obtaining time-varying dynamic conditional correlation coefficients between variables and provides more detailed information in the analysis of time-dependent co-movements compared to the unconditional correlation analysis. The DCC-GARCH model is considered a powerful model because it explains the time-varying volatility spillovers between commodity assets as well as providing information about the volatility of the assets. Examining the time-varying correlation coefficients of returns and volatility between petroleum and precious metals can provide more detailed information about the relationship between the variables. Thus, it is possible to reveal the relationship among the time-varying risks and returns of commodity assets. To the author's knowledge a detailed study of the applications of the DCC-GARCH model to assess the behaviour of the time-varying return and risk spillovers between oil and precious metal markets induced by the COVID-19 pandemic has not been undertaken. Therefore, in this study, the dynamic conditional correlation coefficients, which vary over time, are obtained by the DCC-GARCH method. The main advantage of using this method in the measurement of return and risk is that it can reveal the change that the return or risk has exhibited during the analyzed period. Therefore, return or risk can be revealed not as a single variable calculated for a certain period, but as a time series that can be examined how it changes over time.

To sum up, the rest of the paper is structured as follows. Section 2 reviews the related literature. Section 3 provides the data, the model, and the econometric methodology. Section 4 reports the empirical results. Finally, Section 5 concludes the paper.

## 2. Literature review

Given the emerging financial attribute of oil markets globally, the price changes risks arising from significant fluctuations in the supply and demand of oil are closely monitored by investors as well as firms or individual users whose energy costs hold a significant part in their total costs. Since the changes in oil prices have been more synchronized with various commodity market returns, including precious metals, in recent decades, the spillover effects between oil and precious metals has been the focus of a growing literature (Ewing and Malik, 2013; Mensi et al. 2015, 2017; Reboredo and Ugolini, 2016; Awartani et al., 2016; Yaya et al., 2016; Maghyereh et al., 2017; Rehman et al., 2018; Zhang et al., 2018; Chen and Qu, 2019; Balcilar et al., 2019; Dutta et al., 2019., Shahzad et al., 2019). Among these studies, Ewing and Malik (2013) conducted a study to estimate the volatility spillover effects between gold and oil futures incorporating structural breaks by using employs univariate and bivariate GARCH models with breaks, and reported strong evidence in favor of transmission of volatility between gold and oil returns. A study by Mensi et al. (2015) investigated the time-varying relations of a major oil-based frontier stock market with major commodity futures markets such as oil, gold and silver using the bivariate DCC–FIAPARCH approach with and without structural breaks. They found strong evidence of diversification benefits, hedging effectiveness and downside risk reductions. Working with daily data by separating the period of 1986–2015 into periods before and after the global crisis, Yaya et al. (2016) found evidence that the returns spillover effect runs bilaterally before the crisis whereas after the crisis a unidirectional spillover relation from gold to oil market begins to occur. In addition, the lack of a returns spillover effect from oil to gold after the recent crisis was also interpreted as a measure of the optimum allocation weights and the hedge rate. By employing structural vector autoregression (SVAR) model, Rehman et al. (2018) analyzed the impact of oil shocks on precious metals returns. They showed evidence of that there is a significant spillover effect from the aggregate demand shock to the monthly returns of the precious metals such as silver, copper, palladium and platinum except gold returns, and also after 2010, the oil specific demand shock has a positive net spillover effect on precious metals except palladium. Zhang et al. (2018) examined the effects of global crude oil price shocks on China's precious metals market such as gold and platinum by utilizing the meliorated autoregressive conditional jump intensity (ARJI) model and the ARMA-GARCH model. The findings reveal that the impact of expected shocks in oil prices on the precious metals returns is negative due to the profitability of capital, while unexpected shocks have a positive effect. Moreover, it is seen that the platinum market is more sensitive to oil price shocks than the gold market. Investigating the spillover effects and dynamic correlation between China's precious metals and international crude oil, Chen and Qu (2019) revealed that the volatility of the respective prices of international crude oil and precious metals is the leverage effect. In the study, it is emphasized that gold and silver unlike crude oil are more sensitive to the positive news flow, and the dynamic correlation between the oil and all of the precious metals is usually positive. It is also concluded that China's precious metals are influenced by the volatility of international crude oil, which is a reflection of the volatility spillover effect of international crude oil. Yildirim et al. (2020) examined the return and volatility spillover effect between oil price and precious metal prices by adopting the time-varying causality-in-variance approach. The findings reveal that there is a volatility spillover effect from the oil market to the precious metal market, and that during the global financial crisis there is a volatility spillover from oil to other precious metals such as gold, silver and platinum, excluding palladium.

Among limited set of studies examining risk spillovers between oil prices and precious metal prices, Awartani et al. (2016) examined the directional risk transfer from oil to precious metals (and also including several variables) utilizing the implied volatility indexes. the empirical findings indicated that there is moderate level of risk spillover from oil to precious metals (for gold and silver were around 11.0% and 11.1% respectively), whereas the volatility crossover from precious metals to oil is negligible. In the study, it is emphasized that these results are due to the fact that the oil market plays a decisive role in the risk relationship between oil and precious metals. By employing the multivariate DECO-FIAPARCH model and the spillover index approach proposed by Diebold and Yilmaz (2012), Mensi et al. (2017) revealed that the oil, gold, energy, finance, technology and telecommunication sectors are the net receivers of risk spillovers. Apart from this, the study obtained findings that gold offers better portfolio diversification contributions and downside risk reductions than oil. Recently, Shahzad et al. (2019) analyzed the upside/downside spillover effects of oil price on five precious metal prices using a novel VAR for VaR and the cross-quantilogram approaches. They found consistent evidence in support of systematic downside risk spillovers as the impact of downward oil price movements for gold, silver and palladium markets, unlike titanium and platinum. Mensi et al. (2020) examined co-movements, risk spillovers, and portfolio implications between precious metals and energy futures markets using the spillover index, different wavelet approaches, and different diversification tools. They found that dynamic volatility between markets intensifies during the financial and oil crises, and gold and oil contribute net to volatility, while the remaining markets are a net risk receiver regardless of the market situation.

There are also empirical studies that reveal an increased connectedness among global financial and commodity markets during pandemics such as SARS, MERS, EBOLA, and COVID-19 (see Chen et al., 2009; Del Giudice and Paltrinieri, 2017; Ichev and Marinč, 2018; Chen et al., 2018; Ji et al., 2020; Farid et al., 2021; Mensi et al., 2021; Musali 2021; Salisu et al., 2021). Among the studies considering the effects of the COVID-19 pandemic, Dutta et al. (2020), investigated the safe haven properties of Bitcoin and gold with oil markets. They found that during the COVID-19 pandemic, gold served as a safe haven for both the WTI and Brent crude oil markets. Using threshold and Markov-switching regression models, Adekoya et al. (2021) conclude that gold can hedge against market risks associated with global oil and stock markets during the COVID-19 pandemic period. They also emphasize that the protection of gold increases during periods of higher oil and stock prices, and therefore investors seeking for short-term collateral and diversification may prefer gold. Mensi et al. (2021) analyzed the volatility spillover between crude oil and precious metals such as gold, silver, platinum and palladium, and the role of oil as a hedging instrument against the four precious metals, using the DCC and ADCC-GARCH models. The findings revealed that shocks to oil or precious metals had asymmetrical effects on the correlations between the assets studied, especially when economic conditions were uncertain. In addition, the study emphasized that the cheapest hedge was long Brent oil and short gold, the platinum-Brent oil portfolio was the most expensive hedge, while platinum provided the best hedging effectiveness, during the COVID-19 pandemic. Salisu et al. (2021) considered the returns and volatility spillover relationship between crude oil and precious metal returns with the asymmetric VARMA-GARCH model. The findings provide evidence that precious metals such as silver, platinum and palladium, especially gold, play an important role as a safe haven against crude oil price risks, particularly during the pandemic period. Using time-varying Granger-causality tests in mean and in variance, Yildirim et al. (2021) empirically investigated volatility spillover between oil price and precious metal prices. The causality-in-mean test results revealed that oil price is Granger cause of all precious metals. In addition, the causality-in-variance test results also pointed out that there is a volatility spillover effect from the oil market to the precious metals market. In the study, it is emphasized that this volatility spillover effect is especially strong after the 2000s. Using the BEKK-MGARCH model, Yousaf (2021) examined the risk transmission from the COVID-19 to precious metal and energy markets. Empirical findings reveal that the risk transmission from the COVID-19 to the gold, palladium and Brent oil markets is significantly negative and these markets have safe-haven characteristics during the pandemic.

## 3. Data and methodology

In this paper, we investigate dynamic correlation and level and variance causality relationship between major commodities (including gold, silver, palladium and platinum) and oil prices by employing daily data covering 01.01.2019–14.04.2021 periods. All commodity and oil price variables are obtained from Bloomberg Terminal. Natural logarithms of the variables are employed for dynamic correlation analysis and causality tests. Table 1 presents the descriptive statistics of the variables.

According to Table 1 average daily natural logarithm of gold, silver, palladium, platinum and oil prices are 7.373, 2.927, 7.549, 6.807 and 3.969 respectively. Standard deviations for natural logarithm of the gold, silver, palladium, platinum and oil prices are 0.139, 0.220, 0.219, 0.127 and 0.271 respectively. Standard deviations are less for gold and platinum prices whereas it is high for oil, silver and palladium prices. Moreover, normal distribution assumption is not valid all investigated variables according to Jarque-Bera test. Positive skewness value for the natural logarithm of silver and platinum indicates right skewed distribution and negative skewness value for the natural logarithm of gold, palladium and oil prices indicates left skewed distribution. The positive kurtosis values for all investigated variables shows the existence of fat tail characteristics of the distribution.

For empirical modeling, we first investigate static and dynamic correlation relationship between main metal commodities including gold, silver, platinum and palladium and oil prices. We employ DCC-GARCH model in order to investigate time-varying correlation between main metal commodities and oil prices. DCC model is the generalized version of the Bollerslev's (1990) constant conditional correlation estimator and first introduced by Engle (2002). The main advantage of DCC model is to investigate changes in conditional correlations over sample and thus to analyze the dynamic relationship between two variables. Estimating correlation coefficients of the standardized errors and directly take heteroscedasticity into account is the second advantage of the DCC model (Chiang et al., 2007). Caporin and McAleer (2013) criticized DCC models. They offer DCC model not to be used as a main model and to be used as filter or diagnostic check.

After static and dynamic correlation check, we investigate causality relationship between oil prices and main metal prices including gold, silver, palladium and platinum. We employ both level and variance causality test. In order to investigate causality relationship in level, we employ Toda and Yamamoto (1995) causality test and in order to analyze the causality in variance, we used Hafner and Herwartz (2006) variance causality test.

To investigate the level causality direction of between main metal and oil prices, we used Toda and Yamamoto (1995) causality test. The Toda-Yamamoto test has superior properties from the conventional Granger causality test and it eliminates pre-testing need for co-integration. The integration order of variables is not important, which means the variables could be I(0) or I(1). Therefore, Toda-Yamamoto (1995) [1] test avoids the pre-test bias.

**Table 1**
Descriptive Statistics for the sample period (01.01.2019–14.04.2021).

| | lgold | lsilv | lpal | lplat | loil |
|---|---|---|---|---|---|
| Mean | 7.373 | 2.937 | 7.549 | 6.807 | 3.969 |
| Median | 7.363 | 2.869 | 7.570 | 6.788 | 4.085 |
| Maximum | 7.632 | 3.372 | 7.961 | 7.174 | 4.312 |
| Minimum | 7.147 | 2.483 | 7.140 | 6.382 | 2.962 |
| Std. Dev. | 0.139 | 0.220 | 0.219 | 0.127 | 0.271 |
| Skewness | −0.129 | 0.501 | −0.221 | 0.632 | −1.268 |
| Kurtosis | 1.737 | 1.796 | 1.684 | 3.685 | 4.216 |
| Jarque-Bera | 41.319 | 61.026 | 47.931 | 51.408 | 196.748 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Observations | 597 | 597 | 597 | 597 | 597 |

***Notes:*** The table indicates the summary of the statistics for the variables. *LGOLD, LSILV, LPAL, LPLAT and LOIL* represent the natural logarithm of gold price, silver price, palladium price, platinum price and oil prices respectively.

After level causality check, we investigate causality in variance for main metal and oil prices. Hafner and Herwartz (2006) variance causality test used for variance causality check. Hafner and Herwartz (2006) test based on the LM principle and produce superior results over Cheung and Ng (1996) method. Cheung and Ng (1996) test based on the cross-correlation function and Portmanteau test. Cheung and Ng (1996) test suffers from significant oversizing for small and medium samples. However, Hafner and Herwartz (2006) [2] test produce robust results when sample is small and gain of LM test increase depending on the sample size (Nazlioglu et al., 2013).

Finally, we investigate dynamic correlation between conditional variance of basic metal and oil prices. We obtain conditional variance of basic metal and oil price variables by employing ARCH family models including ARCH, GARCH, EGARCH and TGARCH models. In order to obtain conditional variance of the oil price and basic metals including gold, silver, palladium and platinum prices, we estimate alternative ARCH family models for every variable and define best fit model according to their forecast performance criteria's including RMSE, MAE, MAPE. After we found best fit ARCH family model, we obtain conditional variance of the model for proxy of volatility of the investigated variable.[3] Then, we investigate dynamic correlation between conditional variance of main metal and oil price variables by employing DCC model.

## 4. Results

In the empirical modeling, we first investigate static and dynamic correlation relationship between main metal prices and oil price. Table 2 presents static correlation coefficients between main metal prices including gold, silver, palladium, platinum and oil price over our sample period.

According to Table 2, there is negative correlation between metals including gold, silver and palladium and oil prices and positive correlation between platinum and oil price over our sample period.

After the static correlation analysis, we investigate dynamic correlations between main metal prices and oil price by using DCC model. Dynamic correlation coefficients obtained from DCC model is presented at Fig. 1 below.

In Fig. 1, the dynamic correlation coefficients between oil and precious metal prices are seen. In all graphs, it is seen that the relationship between main metal and oil prices exhibits heterogeneous behavior throughout the period. For the return series, the relationship between oil prices and precious metals exhibits a rather complex structure. In the first two panels of the figure, the relationship between oil and return series related to gold and silver prices is seen. As oil triggers cost inflation, the demand for gold increases. Therefore, it is expected that there will be a theoretically positive relationship between

**Table 2**
Static correlation coefficients.

| | lgold | lsilv | lpal | lplat | loil |
|---|---|---|---|---|---|
| **lgold** | 1 | 0.824 | 0.850 | 0.410 | −0.561 |
| **lsilv** | 0.824 | 1 | 0.739 | 0.752 | −0.065 |
| **lpal** | 0.850 | 0.739 | 1 | 0.569 | −0.379 |
| **lplat** | 0.410 | 0.752 | 0.569 | 1 | 0.407 |
| **loil** | −0.561 | −0.065 | −0.379 | 0.407 | 1 |

these two commodities. There is a mostly negative correlation between oil and gold and silver for the entire period. In this case, it can be stated

[1] Tekin et al. (2017) can be used for the application of Toda and Yamamoto (1995) model.

[2] Nazlioglu et al. (2013) and Nazlioglu et al. (2015) papers could be used for the technical details of the Hafner and Herwartz (2006) test.

[3] For technical details Güngör et al. (2021) paper could be investigated.

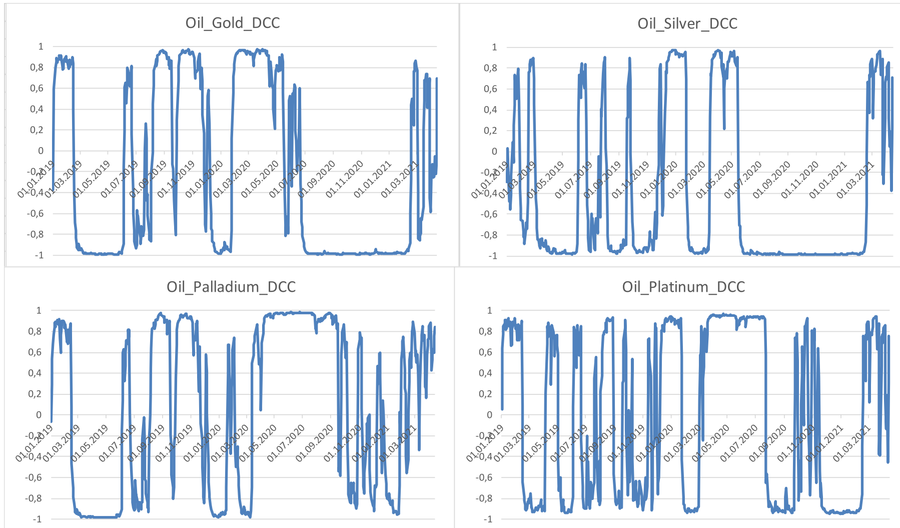


**Fig. 1.** Dynamic correlation coefficients between main metal and oil prices.

that gold and silver mostly showed the feature of safe haven in the face of oil price changes throughout the period. In other words, investors increase the demand for gold and silver in the face of oil price shocks. This shows that oil is an important economic conjuncture variable as a commodity, in other words, it follows the economic conjuncture. In this case, gold and silver, on the other hand, constitute an alternative instrument to oil.

There is a positive correlation between oil price returns and palladium and platinum price returns for most of the period. The reason for this is that palladium and platinum metals find a place in the economy as a production tool (input) rather than an investment tool and follow the economic conjuncture by acting together with oil commodity.

The sectors that use platinum the most are respectively; automotive with 36%, jewellery with 26%, industry with 23% and financial investment with 15% (World Platinum Investment Council, 2020). Palladium is a chemical element similar to platinum. This situation explains the similarity of the price movements of the two metals. 85% of palladium is used in the automotive industry. Apart from this, it is used in the electronics industry, dentistry and jewellery. The largest producer of platinum and palladium mine are Russia, while the most concentrated consumers are China and the USA. With the emergence of the Corona virus epidemic, the decrease in production in China and the USA has led to a decrease in the demand for these metals. In this context, both oil and platinum and palladium prices are positively correlated as cyclically sensitive metals.

Following static and dynamic correlation analysis, we investigate causality relationship between basic metal and oil prices by employing level and variance causality tests.

In order to investigate level causality relationship between basic metal and oil prices, we employ Toda and Yamamoto (1995) causality test. Toda and Yamamoto (1995) test results are presented in Table 3.

After we could not find any significant causality relationship in level, we investigate variance causality by employing Hafner and Herwartz (2006) variance causality test. Table 4 presents Hafner and Herwartz (2006) variance causality test results.

According to Table 4, we found unidirectional causality running from gold, palladium, platinum prices to oil prices in variance by employing Hafner and Herwartz (2006) variance causality test. We found no causality relationship in variance between silver and oil prices.

For sum, in level we found no causality relationship between basic metal and oil prices. However, in variance we found unidirectional causality running from gold, palladium, platinum prices to oil prices by employing Hafner and Herwartz (2006) variance causality test.

**Table 3**
Toda and Yamamoto (1995) Test results.

| From | To | Test Statistics | Prob Value | Results |
|---|---|---|---|---|
| loil | lgold | 1.351 | 0.245 | No Causality |
| lgold | loil | 0.056 | 0.813 | No Causality |
| loil | lsilv | 2.567 | 0.110 | No Causality |
| lsilv | loil | 0.021 | 0.883 | No Causality |
| loil | lpal | 0.029 | 0.863 | No Causality |
| lpal | loil | 1.364 | 0.243 | No Causality |
| loil | lpat | 0.493 | 0.482 | No Causality |
| lplat | loil | 0.867 | 0.352 | No Causality |

According to Table 3, we find no causality relationship between main metal (including gold, silver, platinum and palladium) and oil prices in level by employing Toda Yamamoto (1995) test.

**Table 4**
Hafner and Herwartz (2006) Variance causality test results.

| From | To | Test Statistics | Prob Value | Results |
|---|---|---|---|---|
| loil | lgold | 6.183 | 0.044 | Causality |
| lgold | loil | 1.482 | 0.476 | No Causality |
| loil | lsilv | 0.566 | 0.753 | No Causality |
| lsilv | loil | 0.284 | 0.867 | No Causality |
| loil | lpal | 15.528 | 0.000 | Causality |
| lpal | loil | 1.005 | 0.605 | No Causality |
| loil | lpat | 17.336 | 0.000 | Causality |
| lplat | loil | 0.608 | 0.737 | No Causality |

Finally, we investigate dynamic correlation between conditional variance of basic metal and oil prices. In order to obtain conditional variance of basic metal prices and oil price variables, we estimate alternative ARCH family models (including ARCH, GARCH, EGARCH, TGARCH models) for each variable. Then we compare alternative models according to their forecast performance. By employing RMSE, MAE, MAPE forecast performance criteria's, we choose the best fit model for every variable and obtain conditional variance of the models for proxy of volatility of the variables.[4] After we obtain conditional variance of each variable, we investigate dynamic correlation coefficients between conditional variance of oil price and main metal

[4] We did not report alternative ARCH family model estimates and forecast performance comparison tables for each variable in order to save space. The results could be taken from authors upon interest.

prices by employing DCC model. By doing so, we investigate dynamic correlation between main metal and oil prices in both level and variance.

Dynamic correlation coefficients between conditional variance of oil price and main metal prices are presented in Fig. 2.

When DCC GARCH results on risk transfer between petroleum and precious metals are examined, it is seen that there is a positive correlation in most of the period. This situation shows that the volatility that will arise in oil prices and precious metal prices is transferred. In other words, the risks that arise in financial markets spread. Ewing and Malik (2013), Mensi et al. (2015), Yaya et al. (2016) (after the recent financial crisis), Rehman et al. (2018), Zhang et al. (2018), Chen and Qu (2019) and Yildirim et al. (2020) similarly found evidence of the spillover of volatility between oil and precious metals. An important issue here is whether there is a meaningful change in the correlation between oil and precious metal before and after the Covid epidemic. Therefore, our study presents evidence of oil-precious metals correlations for the pre-crisis and post-crisis period.

In Table 5, Descriptive statistics for the time-varying conditional correlations can be seen for before COVID-19 periods (before December 1, 2019) and COVID-19 period (after December 1). First of all, it is seen that the relationship between oil and precious metals is negative on average in the pre- and post-COVID-19 period. When the results for the return series are examined, a significant change is observed in the absolute value of the correlations between oil and precious metals. While oil and gold have a stronger negative relationship and the negative relationship between oil and silver seems to have weakened during the COVID-19 period. On the other hand, the correlations between oil and platinum and palladium turned positive in the COVID-19 period while they were negative in the before COVID-19 Period. In other words, with the crisis period, oil, platinum and palladium variables started to move in the same direction. On the other hand, it is seen that the highest and lowest values change. This shows that the stability of the correlations between the series in the COVID-19 period become unstable.

When it is examined the risk transfer in the COVID-19 period, it is seen that the relationship between oil and precious metals has strengthened (the average of the return series has increased). On the other hand, it is seen that the stability of the oil-silver relationship, in which the volatility transfer between oil and gold, palladium and platinum series became unstable, stabilized during the COVID-19 period. On the other hand, while the volatility transfer between oil and gold, palladium and platinum series became unstable, oil-silver volatility transfer seems to stabilize in the COVID-19 period.

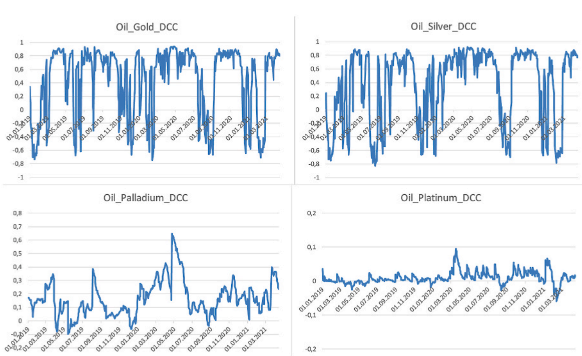


**Fig. 2.** Dynamic correlation coefficients between volatility of the main metal and oil prices.

## 5. Conclusion

Increasing uncertainties and price fluctuations in the world economy make risk management and portfolio diversification inevitable for investors. In risk management, the interactions of derivative products such as precious metals are important in determining investment strategies. it is discussed in the literature that the correlation between low-correlation assets taken into the portfolio to maximize the expected return of investments within a tolerable risk level under ordinary market conditions may increase in crisis periods. Therefore, in our study, oil and precious metal price returns and volatility transfer are investigated by correlation and causality tests. An important contribution of our study is that it uses time-varying methods as well as taking into account the impact of the COVID-19 pandemic.

According to the results of the dynamic correlation coefficients between oil and precious metal prices, it is seen that the relationship between main precious metals and oil prices exhibits heterogeneous behavior throughout the period. There is a negative correlation between oil and gold and silver for most of the entire period. In this case, it can be stated that gold and silver mostly showed the feature of safe haven in the face of oil price changes throughout the period. There is a positive correlation between oil price returns, palladium and platinum price returns for most of the period. The reason for this is that palladium and platinum metals find a place in the economy as a production tool rather than an investment tool and follow the economic conjuncture by acting together with oil. Ewing and Malik (2013), Mensi et al. (2015), Yaya et al. (2016) (after the recent financial crisis), Rehman et al. (2018), Zhang et al. (2018), Chen and Qu (2019) and Yildirim et al. (2020) similarly found evidence of the spillover of volatility between oil and precious metals.

Uncertainties in the global economy have increased due to the COVID-19 Pandemic, and there has been a decrease in global production and demand. The increase in macroeconomic risk has led investors to consider hedging methods. In this context, they attracted more attention as an alternative investment tool with the increase in the financialization of commodities during crisis periods. When the effects of the COVID-19 epidemic on the relationship between oil and precious metals are examined, it is seen that the relationship between oil and precious metal returns in the pre- and post- COVID-19 period is negative on average. While oil and gold have a stronger negative relationship during the COVID-19 period, the negative relationship between oil and silver seems to have weakened. On the other hand, the correlations between oil and platinum and palladium turned positive in the COVID-19 period while it was negative in the before COVID-19 Period. Thus, with the crisis period, oil, platinum and palladium variables started to move in the same direction. On the other hand, there has been a change in the stability of the relations between the COVID-19 period and the series, and that the relations have become unstable. The volatility transmission between oil and precious metals has strengthened (the average of the return series has increased) in the COVID-19 period. Dutta et al. (2020), investigated the safe haven properties of Bitcoin and gold with oil markets and they similarly found that during the COVID-19 pandemic, gold served as a safe haven. This study, on the contrary, considers all the main precious metals and presents the results before and after COVID-19 period comparatively.

When the causality test results are examined, it is seen that there is no causality relationship for the return series. However, it has been observed that there is a one-way variance causality relationship from oil prices to gold, platinum and palladium.

As a result, it is seen that the COVID-19 pandemic has strengthened the transfer of volatility from oil to precious metals. Especially gold and silver, as an investment tool, have the safe haven feature in times of crisis. On the other hand, platinum and palladium prices are in a linear relationship with oil prices.

## CRediT author statement

Durmuş Çağrı Yıldırım: Conceptualization, Supervision, Methodology, Software, Data curation, Writing- Original draft preparation,

**Table 5**
Descriptive statistics for the time-varying conditional correlations.

| | Level | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stats. | Oil - Gold | | Oil - Silver | | Oil - Palladium | | Oil - Platinum | |
| | Covid Period | Before Covid | Covid Period | Before Covid | Covid Period | Before Covid | Covid Period | Before Covid |
| **Min** | −0.99054 | −0.99071 | −0.98632 | −0.98323 | −0.98069 | −0.98352 | −0.94577 | −0.94162 |
| **Max** | 0.97387 | 0.97049 | 0.97409 | 0.90269 | 0.98347 | 0.97341 | 0.96503 | 0.93104 |
| **Mean** | −0.34083 | −0.01526 | −0.38027 | −0.49538 | 0.20084 | −0.05148 | 0.07990 | −0.11705 |
| **Std.Dev.** | 0.80426 | 0.84347 | 0.83167 | 0.64013 | 0.76669 | 0.83762 | 0.83881 | 0.75804 |
| | **Volatility** | | | | | | | |
| **Stats.** | **Oil - Gold** | | **Oil - Silver** | | **Oil - Palladium** | | **Oil - Platinum** | |
| | Covid Period | Before Covid | Covid Period | Before Covid | Covid Period | Before Covid | Covid Period | Before Covid |
| **Min** | −0.74144 | −0.73753 | −0.78156 | −0.82098 | −0.06098 | −0.09818 | −0.05898 | −0.02493 |
| **Max** | 0.94138 | 0.93423 | 0.91985 | 0.88802 | 0.64942 | 0.38641 | 0.09580 | 0.03592 |
| **Mean** | 0.45074 | 0.42024 | 0.47713 | 0.20716 | 0.20421 | 0.10854 | 0.01484 | 0.00252 |
| **Std.Dev.** | 0.51022 | 0.50052 | 0.49635 | 0.55556 | 0.13806 | 0.09709 | 0.02108 | 0.00840 |

Visualization, Investigation, Reviewing and Editing. Ömer Esen: Supervision, Validation, Methodology, Writing- Original draft preparation, Visualization, Investigation, Reviewing and Editing. Hasan Murat Ertuğrul: Methodology, Writing- Original draft preparation, Visualization, Investigation, Reviewing and Editing.

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