Dynamic Spillovers Between Crude Oil Price and Gold Price: Empirical Evidence

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Abstract

This paper intends to explore the volatility transmission amid crude oil price and the gold price in India employing BEKK-GARCH, CCC-GARCH, and DCC-GARCH model. Further, the model's outcome is used to estimate the optimal weights and hedge ratios for oil -bullion portfolio holdings. The outcome of the study indicating a historic relationship among oil and the gold price in India. The results also specify that the DCC GARCH model is more preferred than CCC GARCH and BEKK GARCH model since the DCC GARCH model provides more evidence of volatility spillover between the oil and gold returns. The analysis postulating that the gold price is sensitive to oil price changes. Hence, gold price changes could be a predictor for oil returns in India. The estimated hedge ratio postulates that gold is a valuable hedge for the fluctuations in the oil price in India. The study results provide a valuable insight to the investors/ institutional investors to understand the spillover effect to make better investment decisions by diversifying their risk.

Keywords: Oil Price, Gold, GARCH, Hedge Ratio, Diversification.

JEL Classification: G11, G12, G15

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1. Introduction

Gold and Oil received ample deliberation in the economic literature due to their economic contentions. The most cherished metal gold has traditionally been a safe investment tool. Baur and Lucey (2010) examined the role of gold as safe-haven assets during extreme economic and market turmoil in the US, UK, and Germany. They provided a supporting view for gold investment. Many scholars have explored this issue and stated positive thoughts. Further gold market was assumed as a symbol of precious metal markets.

Crude oil is observed as an input in the production of precious metals. So, an increase in oil price leads to an adverse influence on the production of valued metals. Crude oil is a global commodity, and it is one of the significant sources of energy that indirectly affects costs such as transportation, manufacturing, and heating. The U.S. is the world's largest oil-producing country, and India is the second-largest contributor to the world's yearly oil demand growth, second only to China. Oil consumption in India grew by 4.8 percent between 2007- 2017. In 2018, oil consumption increased by 5.3 percent in India. (BP Statistical Review of World Energy 2019). The global crude oil prices have been steadily rising, and it crossed $80/barrel in May 2018; and this abrupt surge in prices has a significant impact on various segments of the Indian economy. It surges the price level in the economy and shrinking the profitability of companies. Further, an increase in oil price increases inflation and reduces the domestic currency. The fluctuations of crude oil prices influence the industries that leading to enhanced risks and challenges. The precious metals market has sturdier financial features in comparison to other markets. It is debated that the oil price fluctuations are hedge by investing in metal and agricultural assets.

Metal markets are particularly sensitive to energy markets. Crude oil prices effectively transmit shocks to other commodity markets. Uncertainty has always driven investors to seek safer assets, particularly gold. Gold is often used as a managing risk instrument in hedging. Since the oil and gold markets are asymmetrically related by their shocks to each other, we have taken these two important commodities to examine their spillover effect. Soytas et al. (2009) debated that investors jointly use oil and gold in developed and developing countries to diversify their portfolios. If the oil price influencing the metal price, in that case, the movements of oil prices can be easily observed and predicted the gold price, which will enable the policymakers to frame an appropriate economic policy. Scholars have given their opinion that if the correlation between two markets rises, a surprising event in the market causes return and volatility variation. Further Intermarket relationships postulate the contagion effects, which minimizes the advantage of international portfolio diversifications. The influence of crude oil on the development of the economy has been received attention amongst energy economists in recent years. The link between crude oil and gold is significant for investors, policymakers, corporate and portfolio managers. Since the precious metal markets are more intense to oil price shocks, it necessitates examining the spillover effects between oil and metal markets considering both risks and return. However, the literature exploring the influence of oil price on the commodity futures, especially the bullion market, has been limited. Hence, the rationale behind considering oil price and gold price futures in our study is the dearth of literature and the present study is trying to address this gap. The present study focuses on finding the correlation and volatility spillover effect of crude oil price on gold price employing the BEKK-GARCH, CCC-GARCH, and DCC-GARCH model, a country which is observed as one of the economics that are going to be amongst the robust growing economics in emerging countries. Secondly, the study estimates the findings from the model to analyses the diversification and hedging efficacy transversely oil and gold return. The present work improves the earlier outcomes and provides additional insights into the existing literature.

The paper is structured as follows: Pertinent past research is deliberated in section 2; section 3 describes the data and methodology. Section 4 explains empirical results. Finally, the concluding observations are presented in section 5.

2. Literature Review

In the energy market, oil is often deliberated as a leading factor for changing the price of other commodities. Cashin et al. (1999) explored the changing long-run behavior of world commodity prices and demonstrated little evidence of long-run trend decline in commodity prices. Mackenzie et al. (2001) examined the volatility of precious metals, and their findings do not provide any asymmetric effect in the metal markets. The concluding observation suggests that the TGARCH model executes best to capture leverage effects in the commodity futures market. Baffes(2007) observed the changes of crude oil price to the prices of most other internationally traded commodities, indicating that precious metal price is strongly retorted to the crude oil price.

Baem (2008) found that a positive linkage between oil and gold price and oil plays an instrumental role in defining the price of precious metals. Hammoudeh and Yuan (2008) observed that the increase in metal prices leads to a surge the oil prices. The study attributed that the transportation and production costs increased with the rise in oil prices. Soytas et al. (2009) explored the short run and long run association between metal price and oil price in Turkey and their observation indicating that oil price does not have predictive power over the gold price. Narayan and Narayan (2010) examine the linkage amid oil and gold price at different maturities, indicating that gold is an effective hedge against inflation.

Hence, oil and gold can mutually consider for the prediction of the prices. Zhang and Wei (2010) investigated the integration amid the oil market and the gold market. The findings of their study indicating the long-term equilibrium association between the two markets. The study also showed that crude oil price changes unidirectional, influencing the gold price changes. Sari et al. (2011) observed the long-term equilibrium relationship amid the US dollar exchange rate, metals, and crude oil prices. Their study stipulates that some part of the risk can be minimized by investing in crude oil, metals, and the Euro. Simakova (2011) examined the relation between gold and oil price and demonstrated a cointegrating relationship between oil and gold prices.

The study was also indicating the presence of causal linkage between them. Filis et al. (2011) examined the correlation between oil prices and stock market prices using the DCC-GARCH model. Their outcomes signposted that oil price changes are influencing the stock markets negatively. Juan C (2013) investigated the dependency structure between gold and oil price movements and demonstrated a substantial presence of dependence amid gold and oil, signifying that gold can act as a safe haven against oil market pressure. Chkili (2016) examined the asymmetric and long memory influence of crude oil, natural gas, gold, and silver prices, indicating the existence of leverage effect in energy but provides inverse results in gold and silver. The study demonstrated that the leverage effects in the energy market are more persistent than in the precious metal market. Aviral and Sahadudheen(2015) investigated the relationship between real oil price and real gold price in India and found that increase in real oil price leads to increased gold price; however, gold price shocks have an asymmetric effect on oil. In their research, Zhu et al. (2015) proposed that changes in global crude prices have a substantial impact on changes in the price of precious metals in both the long run and short run. Mensi et al. (2017b) used daily data of crude oil, gold, aggregate Dow Jones Islamic index, and ten sectorial stocks to observe the time-varying correlations and the risk spillovers amid them. The analysis reported that the net receivers of risk spillovers are the oil, gold, financial, technology, and telecommunications subsectors. On the other hand, the net transmitters are consumer goods, consumer services, health care, industrials, and utility sub-sectors of the DJIM index. Mo et al. (2018) observed the long-run relationship amongst the gold market, the US dollar, and the crude oil market. The concluding observations were indicating the existence of a causal relationship amid them. Walid et al. (2020) investigated co-movement and spillover between precious metals and primary energy and found strengthening co-movement between energy and precious metals. Saqib et al. (2021) indicating the evidence of volatility connectedness among equities and significant commodities in the US during the COVID-19 outbreak. Their findings indicated the substantial impact of the COVID-19 pandemic on the volatility linkages of different assets during the pandemic period.

3. Research Method

The data set contains the daily closing price of the crude oil price futures and gold futures. The period spans from 1st January 2008 to 31st May 2019. The crude oil price futures and gold futures data are obtained from the Multi Commodity Exchange of India. The primary rationale behind selecting futures prices is its more significant role in price discovery than that of spot prices. The commodity price changes are observed first in the futures market, followed by the spot market, where the transmission of information from futures to spot happens through arbitrageurs' trade. The same has been confirmed in the work of Ben Ameur et al. (2021). Further, the commodity futures prices are constructed with a futures pricing formula. We add the cost of carrying to the spot prices of the commodity and multiply the resulting value with Euler's number raised to the product of risk-free rate and time to maturity. The cost of carrying comprises the storage costs, interest, insurance, and other incidental expenses. The oil and gold future price returns are transmuted into natural logs before using econometric models.

3.1. BEKK (Baba, Engle, Kraft and Kroner)-GARCH Model

BEKK-GARCH Models helps to disclose volatility interdependence and transmission mechanisms between one market to another market. It also allows the conditional variances and covariance of markets to affect each other. Baba et al. (1990) articulate the BEKK-GARCH model and Engle, and Kroner (1995) conclude it. The BEKK-GARCH model is articulated as:

$$H_t = CC' + A_i'\varepsilon_{t-1}\varepsilon_{t-1}' A_i + B_j' H_{t-j} B_j \quad (1)$$

C is nxn upper triangular matrix. $A_i B_j'$ are nxn parameter matrices, A_i estimates the extent to which conditional variance related to past squared errors and captures the shocks effects on conditional volatility. B_j' measures current levels conditional variances and past conditional variances correlations. It signposts how the current level of conditional volatility is pretentious by past conditional volatility. The variance equations of the BEKK model can be written as

$$H_t = CC' + \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}' \begin{pmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} + \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}' \begin{pmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \quad (2)$$

$where\ b_{12}$ and b_{21}measure the dependency of conditional price volatility, b_{11} and b_{22} signifies volatility persistence, a_{11} and a_{22} indicates own market effects whereas $a_{12} and\ a_{21}$ denotes cross-market results. If the parameters are significant, it specifies the existence of ARCH or GARCH effects.

The conditional variance and covariance equation as follow:

Variance equation expressed as:

$$h_{11,t} = c_1 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + b_{11}^2 h_{11,t-1} + 2b_{11}b_{21}h_{12,t-1} + b_{21}^2 h_{22,t-1} \quad (3)$$

$$h_{22,t} = c_3 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + b_{12}^2 h_{11,t-1} + 2b_{12}b_{22}h_{12,t-1} + b_{22}^2 h_{22,t-1} \quad (4)$$

Co variance equation expressed as:

$$h_{12,t} = c_2 + a_{11}a_{12}\varepsilon_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon_{2,t-1}^2 + b_{11}b_{12}h_{11,t-1}^2 + (b_{21}b_{12} + b_{11}b_{22})h_{12,t-1} + b_{21}b_{22}h_{22,t-1}^2 \quad (5)$$

BEKK GARCH model evaluate the conditional mean and volatility of high-dimensional relationships. It is used to test volatility spillovers between different markets. All these equations specify how shocks and volatility transferred across markets.

3.2. The constant conditional correlation (CCC) Model

Bollerslev (1990) proposed the CCC GARCH model, and the model undertakes that conditional correlations are constant while the conditional variances are time-varying. The conditional covariance matrix expressed as follows:

The conditional covariance matrix expressed as follows:

$$H_t = D_t R D_t = \left(p_{ij}\sqrt{h_{ii,t}h_{jj,t}}\right) \tag{6}$$

$$D_t = diag\left(h_{11\,t}^{1/2}\right) \ldots\ldots\ldots\ldots\ldots\ldots h_{22\,t}^{\frac{1}{2}} \tag{7}$$

$$h_{iit} = c_1 + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{ii,t-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots i = 1 \ldots\ldots\ldots\ldots n \tag{8}$$

Where H_t represents (2x2) conditional covariance matrix, D_t shows dynamic standard deviation matrix and R denotes (2x2) conditional correlation matrix. The conditional variance is h_{ii}.

3.3. The Dynamic Conditional Correlation (DCC) model

DCC GARCH model have the flexibility of univariate GARCH models tied with parsimonious parametric models for the correlations. This model overtly captures the asymmetric response of conditional volatilities to negative returns and allows the correlation component to assume a GARCH type specification. It captures the dynamic time-varying behavior of conditional covariance. It evaluates the volatility spillover across markets. The dynamic Conditional Correlation (DCC) model was established by Engle (2002), which initially estimated the GARCH parameter, then the correlation is calculated.

$$H_t = D_t\, R_t\, D_t \tag{9}$$

In Eq (9), represents the 3x3 conditional covariance matrix, signifies the conditional correlation matrix, and signifies the diagonal matrix with time varying standard deviations on the diagonal.

$$D_t = diag\left(h_{11t}^{\frac{1}{2}}, \ldots . h_{33t}^{\frac{1}{2}}\right) \tag{10}$$

$$R_t = diag\left(q_{11t}^{-\frac{1}{2}}, \ldots . q_{33t}^{-\frac{1}{2}}\right) Q_t diag\left(q_{11t}^{-\frac{1}{2}}, \ldots . q_{33t}^{-\frac{1}{2}}\right) \tag{11}$$

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1 \zeta_{t-1}\zeta_{t-1}' + \theta_2 Q_{t-1} \tag{12}$$

Q_t signifies the symmetric positive definite matrix.

$\bar{Q}$ represents the 3x3 unconditional correlation matrix of the standardized residuals ζ_{it}. The parameters θ_1 and θ_2 are less than one when they sum up. However, the conditional correlation will not be constant if they are significant statically. The dynamic conditional correlation is expressed as:

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,i,t}q_{j,j,t}}} \qquad (13)$$

The correlation estimator is $\rho_{i,j,t}$. The present study estimates the GARCH type models with Quasi Maximum Likelihood estimation (QMLE).

3.4. Hedge Ratios

Kroner and Sultan (1993) pointed out that the hedge ratios are estimated using the conditional volatility. The crude oil and metal price volatility is used to measure hedge ratio as follows:

$$\beta_{xy,t} = \frac{h_{xy,t}}{h_{yy,t}} \qquad (14)$$

$\beta_{xy,t}$ represents hedge ratio amid x and y at time t. $h_{xy,t}$ signifies conditional covariance between the x and y at time t, and $h_{yy,t}$ is termed as the conditional variance of asset y.

3.5. Portfolio Weights

Kroner and Ng (1998) devised the way of constructing optimal portfolio weights from the Multivariate GARCH model. The equation for estimation of optimal portfolio weights is as follows:

$$W_{xy,t} = \frac{h_{yy,t} - h_{xy,t}}{h_{xx,t} - 2h_{xy,t} + h_{yy,t}} \qquad (15)$$

$W_{xy,t}$ is the weight of asset x in one-dollar portfolio of x and y, at time t. $h_{xy,t}$ is defined as the conditional covariance between the asset x and y at time t and $h_{yy,t}$ is termed as the conditional variance of asset y. The weight of asset y at time t is 1-$W_{xy,t}$.

4. Analysis of Results

The descriptive statistics of the variables taken under study are detailed in Table 1.

Table 1. Descriptive Statistics

	OIL	GOLD
Mean	0.001399	0.000838
Std. Dev.	0.445272	0.467818
Skewness	0.523229	0.280364
Kurtosis	22.70835	14.83916
Jarque-Bera	60569.46*	21844.66*
Augmented Dickey-Fuller test	-26.95800*	-26.19015*
Phillips-Perron test	-328.0798*	-415.1517*
KPSS test	0.256189*	0.307096*

Notes: * indicates 1% level of significance

From the descriptive statistics, it observes that crude oil mean returns are higher than a gold return. It is evident from the table-1 that the gold return is more volatile than oil returns. The skewness of both oil and gold is positive, indicating that these series have more extended right than left tail, resulting in more gains than losses. Therefore, it happens for oil since oil skewness is higher than gold. It indicates that the possibility of realizing positive return is better from oil than gold while capitalizing in these markets. The high kurtosis value indicates the leptokurtic nature of the data. The Jarque Bera test is significant, demonstrating the non-normal nature of the data and the presence of heteroscedasticity. Hence, GARCH type models can be used. The table-1 also reports the ADF test, PP Test, and KPSS test. All these tests reveal that all the return series are stationery.

Table 2. Correlations between the Daily Returns of Gold & Oil

	Oil	Gold
Oil	1.000	
Gold	0.696012	1.000

As observed in Table 2, the unconditional correlation reports the strong positive correlation between gold and oil, indicating that increases in oil price placed pressure on investing in gold. The value of correlation for the whole period is 0.69, implying a linear association between them. The time-series graph of the future daily price of gold and oil shows the change in volatility of the variables across the time in fig-1. The big spikes observed at various points of the daily time series indicating the increased volatility of oil and gold in the study.

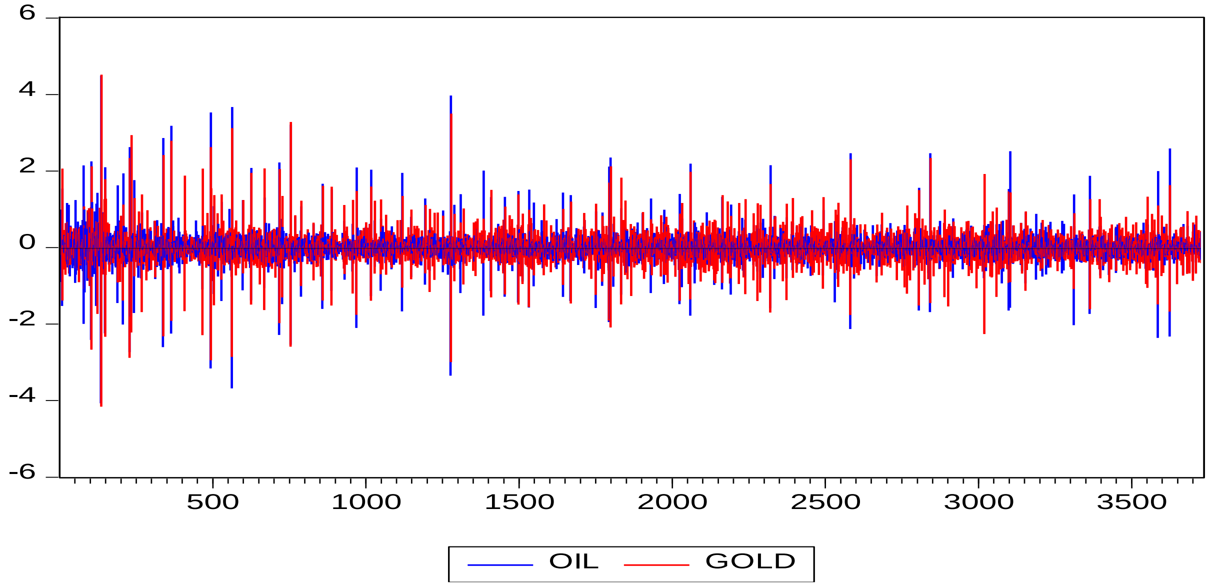

Figure 1. Oil and Gold Returns

Table 3. Estimation of BEKK Model between Oil and Gold returns

Variable	Coefficient	Std Error	T.Stat	Significance
c_{11}	0.257⋆	0.013	19.245	0.000
c_{21}	0.280⋆	0.016	17.636	0.000
c_{22}	0.0001	0.008	0.0013	0.9989
a_{11}	0.593⋆	0.122	4.847	0.0000
a_{12}	0.421⋆	0.114	3.698	0.0002
a_{21}	0.215⋆	0.0006	35.065	0.0000
a_{22}	0.360⋆	0.022	16.114	0.0000
b_{11}	0.534⋆	0.083	6.396	0.0000
b_{12}	-0.433⋆	0.0701	-6.188	0.0000
b_{21}	-0.361⋆	0.0431	-8.368	0.0000
b_{22}	0.634⋆	0.056	11.338	0.0000
LogLikelihood	-2126.0966			
AIC	1.198			
SBC	1.177			

The Variable order is Oil (1), Gold (2). C represents the constant term. The ARCH and GARCH Terms are indicated by a and b respectively. a (1, 2) and a (2, 1) indicate short-term volatility spillover from oil to gold returns and vice versa. b (1, 2) and b (2, 1) indicates long-term volatility spillover from oil returns to gold returns and vice versa.

Notes: * indicates 1% level of significance

The BEKK-GARCH model results are presented in Table 3. The coefficients of oil in the gold equation are positive and significant at 1% level representing that gold return is influenced by the last period oil return. Similarly, the coefficients of gold in the oil equation are positive and significant at a 1 % level, instituting a positive association between the current oil return and the previous gold return. The coefficients a_{11}refers to the ARCH term in oil equation, while coefficients a_{22} refers to the ARCH term in gold equation. Similarly, b_{11}refers to the GARCH term in oil equation, whereas coefficients b_{22} denotes GARCH term in gold equation. ARCH coefficients indicate the past information to the present effect, whereas the GARCH coefficient represents persistence concerning the covariance and return volatility. The coefficients a_{11} (ARCH oil) and b_{11} (GARCH oil), are significant, while a_{22} (ARCH gold) and b_{22} (GARCH gold) are also important, suggesting that surprising oil market news and past news disrupt the conditional volatility of oil and gold returns. The estimated GARCH coefficients, i.e., b_{11} (GARCH oil) and b_{22}(GARCH gold) are statistically significant, demonstrating the considerable presence of long-term persistence amid oil and gold returns. The own conditional ARCH effects of the variables, i.e., a_{11} and a_{22} measuring short-term persistence, are smaller than their respective long-term persistence value.

The BEKK Model witnesses the substantial presence of volatility spillover. It observes from the table-3 that the short-term persistence volatility spillover is found between oil and gold (a_{12}) . In addition, long-term persistence volatility spillover is seen unfavorably between oil and gold(b_{12}) suggesting that their association does not continue long. The GARCH coefficients range from -0.433 to 0.634 compared with the lagged innovation parameter estimates of 0.215 to 0.593, demonstrating that the variance of these prices is more prejudiced by their owned lagged value than recent news, which is reflected by the lagged innovations. The transmission of volatility from oil to gold is -0.433, which implies 1% drop in oil price, transmit 43.3% volatility to the gold price. In contrast, the transmission of volatility from gold to oil is -0.361, suggesting that 1% decrease in gold price leads to transmit volatility of 36.1%, which is low. The influence of information shock is more decisive from oil to gold as compared to gold to oil. The BEKK GARCH Model demonstrates the presence of conditional heteroscedasticity in its return series, indicating that the correlation of volatility exists in Gold and Oil. The analysis postulating that the gold price is sensitive to oil price changes. Therefore, oil price changes could be a predictor for gold returns in India.

Table 4. Estimation of CCC and DCC- GARCH Model between Oil and Gold Returns

	CCC			DCC		
Variable	Coefficient	T.Stat	Significance	Coefficient	T.Stat	Significance
c_1	0.113⋆	6.689	0.0000	0.078⋆	5.383	0.000
c_2	0.099⋆	6.576	0.0000	0.077⋆	5.394	0.0000
a_{11}	0.348⋆	3.767	0.0002	0.361⋆	3.803	0.0001
a_{12}	0.057	1.132	0.2573	0.062	1.134	0.2565
a_{21}	0.189⋆	3.181	0.0015	0.204	2.511	0.0121
a_{22}	0.103⋆	2.992	0.0028	0.150⋆	3.124	0.0018
b_{11}	0.215	1.138	0.2548	0.328⋆⋆	1.9305	0.0535
b_{12}	-0.303	-1.398	0.162	-0.153	-0.8631	0.388
b_{21}	-0.277⋆⋆	-2.002	0.045	-0.179	-1.001	0.317
b_{22}	0.404	2.152	0.0314	0.4563⋆⋆	2.0815	0.0374
p_{21}	0.631⋆	30.642	0.0000			
DCC (a)				0.2116⋆	7.7438	0.0000
DCC(b)				0.4137⋆	5.811	0.00001
Log	-2303.4987			Log		
Likelihood				Likelihood	-2316.1531	
AIC	1.244			AIC	1.149	
SBC	1.272			SBC	1.228	

The Variable order is Oil (1), Gold (2). C symbolizes the constant term. The ARCH and GARCH Terms are indicated by a and b respectively. a (1,2) and a (2,1) indicate short term volatility spillover from oil to gold returns and vice versa. b (1,2) and b (2,1) indicates long term volatility spillover from oil returns to gold returns and vice versa. p_{21} indicates the correlation coefficients between the variables. DCC (a) and DCC (b).

Notes: *, and ** indicates 1%, 5% level of significance

The table-4 exhibits that correlation between gold and oil (p_{21}) are statistically significant, signifying that correlations of shocks exist across markets and volatilities hold high conditional correlations. DCC results show the changing pattern of the influence of volatility of one price on the other. The constant conditional correlation amid oil and gold covers a range of values between -0.277 to -0.303. In contrast, the Dynamic conditional correlation amid oil and gold shows the range between -0.153 to -0.179, which delivers a negative correlation and suggesting a prospect for portfolio diversification. The assessed coefficients DCC (a) and DCC (b) in the DCC model are promising and statistically significant. The DCC (a) reveals the past shocks' effect on conditional correlations, and

DCC (b) shows the previous correlation effect. [DCC (a) + DCC (b)] is less than one signposts the presence of long-run persistence in the conditional volatility, and conditional correlation is mean-reverting. Therefore, the conditional correlations are not constant; the result confirms with Chang et al. (2013) and Majdoub and Mansour (2014), who proposed that conditional correlations are significant in the DCC model. So, if any change occurs in the conditional correlations, it will change and return to previous correlations. The results are also in conformity with Christodoulakis (2007) findings, who debated the presence of long memory in correlations. The conditional correlation outcomes suggest the existence of dynamic and time-varying correlation amid oil and gold markets. The analysis results indicate the presence of short-term and long-term memory influence of oil on the Indian gold market. Therefore, oil prices are a better predictor of gold price movements.

Table 5. Multivariate GARCH Models Comparison

		BEKK Garch	CCC Garch	DCC Garch
Akaike Information Criterion (AIC)	1.198	1.244	1.149	

The diagnostic test for all these models suggests the robustness of the results, based on the Akaike information criterion. If the AIC shows lowest value, the estimated model is well specified, reflecting the robustness of our model. The table-5 presents the AIC for BEKK-GARCH is 1.198, the AIC for CC-GARCH is 1.244 and the AIC for DCC-GARCH model is 1.149. It is evident from the table-5 that the DCC-GARCH model has lowest AIC value. Hence, DCC GARCH Model appeared to be a more preferred model than other models since the DCC- GARCH model produces more evidence of volatility spillover between the asset classes compared to the BEKK-GARCH and CCC-GARCH Model. Additionally, we have selected the preferred model considering the value of AIC. Our results are confirmed with (Sadorsky 2012, Majdoub and Mansour, 2014). Further Log Likelihood is low in case of DCC-GARCH model. Hence DCC-GARCH model is more preferred model than BEKK-GARCH and CCC-GARCH Model for capturing volatility spillover between gold and oil. From the dynamic conditional correlations model, portfolio weights and dynamic hedge ratios are estimated, which are exhibited in Figure 2. The dynamic hedge ratios, as observed in Figure 2, show considerable variability across the period. The hedge ratios for gold/oil hedges are maximum during the period between 2006 and the year 2007, which is observed from the analysis. The hedge ratio for oil/gold hedge is a minimal point during the year 2005.

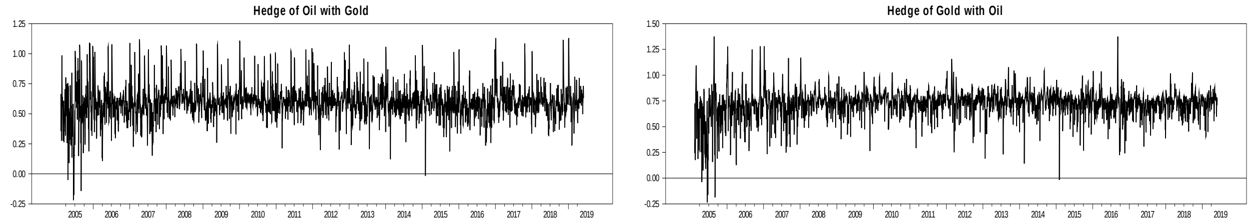

Figure 2. Time Varying Hedge Ratios computed from DCC Model

Optimal portfolio weights, hedge ratio and hedging effectiveness has been computed to help investors to construct optimal portfolio. The hedge ratios and the portfolio weights are specified in Table 6.

Table 6. Hedge Ratio and Portfolio Weights between Oil and Gold returns

	Mean	Std. Deviation	Minimum	Maximum
Hedge Ratio				
Oil/Gold	0.60	0.13	-0.22	1.13
Gold/Oil	0.73	0.13	-0.24	1.38
Portfolio Weights (oil/gold)	0.63	0.16	0.00	1.00

Table-6 exhibits the hedging ratio between oil and gold is 0.60. The hedge ratio indicates that Rs. 1 long position in oil can be hedged for 60-paisa short position in gold. Similarly, Rs. 1 long position in gold can be hedged for 73-paisa short position in oil. As observed from Table 6 for Rs 1 long position in oil, the cheapest hedge is 60 paisa, a short position in gold. According to portfolio weights, the mean weight is 0.63, demonstrating that for an Rs. 1 portfolio, 63 paisa invested in oil, and 37 paisa invested in gold. The results indicate that it is high time for the oil-importing countries to use gold as a hedge against investment in the crude oil market and need to include gold while designing a reserve portfolio.

5. Conclusions

The objective of the present study is to explore the dynamic relation and volatility spillover effects between the changes in crude oil prices and the gold price in India from1st January 2008 to 31st May 2019 using BEKK-GARCH, CCC-GARCH, and DCC-GARCH model. Further, the study tries to examine the hedging ratios and portfolio weights. The BEKK-GARCH Model demonstrates the presence of conditional heteroscedasticity in its return series, indicating that the correlation of volatility exists in Gold and Oil. The results of dynamic conditional correlation suggesting the existence of dynamic and time-varying correlation amid oil and gold markets. Additionally, the conditional correlation results indicating that correlations of shocks exist across markets, and volatilities hold high conditional correlations. The study results also show that the DCC-GARCH model appeared to be a more preferred model than CCC-GARCH and BEKK-GARCH model since the DCC-GARCH model provides more evidence of volatility spillover between the oil and gold returns. The analysis postulating that the gold price is sensitive to oil price changes. Hence, a steady price of crude oil could help to stabilize the metal price in India. In addition, oil price changes could be a predictor for gold returns in India. The outcome of hedge ratios discovers the long position in gold and short position in oil to be the best affluent hedging position. However, gold is a useful hedge for the fluctuations in the oil market, with gold being considered a highly influential metal due to its value as a financial and anti-inflation investment avenue, a better reserve for money, and high storage value. The outcomes of the study have numerous insinuations. Since rising oil prices lead to rising inflation, gold returns retort substantially to oil price changes; inflation can be hedge using gold price. Gold returns significantly reacting to oil price shocks. Hence gold price can be predicted using the change in oil price. The findings would help monetary authorities and policymakers to monitor the price of core commodities in the market. It is also equally important to cultivate strategic oil reserves to resolve oil price shocks. The price movements in oil and gold may also act as a useful indicator for price discovery and a reliable source of information for forecasting price trends in the commodity market. Therefore, the investors and the oil-importing countries can target gold as hedging instruments in the oil market. It is also suggested for oil-importing countries to include gold while designing a portfolio. The policymakers can take dynamic measures to encounter oil price shocks. It is proposed to construct strategic oil reserves to condense the oil price shocks since metals are strategic resources used for the country’s economic development. It is suggested to take measures to abate metal price volatility attributed to global oil price oscillations. The empirical findings are helpful for investors and policymakers for the future economic and financial conditions. The results may have a significant influence on shaping the risk management strategy for individuals and institutional investors participating in energy and metal markets. The analysis and the information obtained from the volatility spillover from oil to the gold market may be instrumental to the investors in making better investment decisions and portfolio diversifications.

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