Linkage between Crude Oil, Gold, INR-USD Reference Rate and Sensex amidst Covid-19 Pandemic: A Cointegration and Causality Analysis

Nilotpal Sarma [1]

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ABSTRACT

The primary purpose of this paper is to analyse the short-run and long-run association between crude oil prices, gold prices, USD-INR reference rate, and stock market index across the COVID-19 pandemic. We have employed Johansen's cointegration test to measure the long-run association among the variables. To measure the short-run association of variables, we employed vector autoregression, and then, to find the direction of causality, we used the Granger causality test. The cointegration test results show that variables are not cointegrated in the pre-crisis as well as during the crisis period; hence, there is no long-run association among the variables. The VAR results show that gold price was influenced by the stock market index in the pre-crisis era; however, during the crisis, no association was observed. Similar results can also be found in crude oil, USD-INR reference rate, gold price, and stock market. The results also show that the relationships among the variables are dynamic and ever-changing in the pre-COVID and during the COVID-19 pandemic.

1. Introduction

From ancient times, Indians have been quite obsessed with yellow metal, specifically known as Gold. Due to many cultural and traditional norms followed by Indian citizens, its use in Indian marriages still makes it one of the most traded commodities in the Indian Commodity market. Though the purchase of Gold in India is linked to certain festivals such as Diwali, dhanteras, or Akshay-Tritia, the digitization of the market has helped keep the demand for Gold quite high throughout the year. Nowadays, a significant amount of Gold is also used in industries such as health, semiconductors, chemical science, etc. However, many researchers, such as (Arfaoui & Rejeb, 2017) and (Baur & McDermott, 2010), regarded Gold as a safe haven investment at the

[1] Email Address: nilotpalsarma62@gmail.com

time of crisis. Basically, when there is a crisis, there is no demand in the economy, and other markets are going down, people tend to find Gold as an alternative investment for their holdings. Since the value of Gold is significantly higher and it is exposed to different kinds of market risks, it has become necessary to study the factors that can influence the price of Gold in different states of the economy.

The COVID-19 economic crisis is a black swan event. It involved a period of lockdown when no industry was operating, and everything was at a halt. The stock market and currency market went through a high level of uncertainty, and it has become extremely volatile. At the same because of various international and national factors, crude oil prices are also in an upward movement in India, and it is believed that an increase in Crude oil causes inflation in the country and, ultimately, a depreciation of the currency and, which also affects the stock market. So, going through such situations, investors generally look for some alternative investments to keep their assets safe and secure, and it is believed that they put their money in Gold, hoping that the value of Gold will not decline (Baur & McDermott, 2010).

So, at this point, it has become necessary to analyze the relationship between Crude Oil prices, Gold Prices, INR-USD exchange rate and the Stock Market Index of India during the COVID-19 economic crisis so that investors and other stakeholders can plan their investments in future. For this purpose, we have used Johansen's Cointegration, vector autoregression, and Granger causality tests to determine the long-run and short-run associations of variables.

The results show that there exists a dynamic relationship between gold price, crude oil price, stock market, and INR-USD reference rate. Contrary to other studies, Gold didn't seem to exhibit safe-haven properties during the COVID-19 crisis. The rest of the paper is organized as section 2 explains a brief literature review, data and methodology are explained in section 3, section 4 presents results, and section 5 concludes the paper.

2. Literature Review

A substantial body of research exists that examines cross-market Cointegration and co-movements, with a particular emphasis on equities and commodities. Many researchers have studied volatility in gold prices and studied the variation in gold prices because of variations in some other asset classes. Ghalayini & Farhat (2020) investigated the relationship between the Gold Price and other macroeconomic variables such as inflation, exchange rate, interest rate, crude oil price and performance of the equity market by employing the Granger causality test and ordinary Least Square and found out that Japanese yen per dollar exchange rate granger cause changes in the price of Gold and in the long run US Dollar is the variable that influences the price of Gold.

Singh & Sharma (2018) studies the relationship between Gold, crude oil, USD rate and Sensex during the US financial crisis of 2008. The analysis was conducted by formulating Johansen's Cointegration test, vector Error Correction Model and VEC Granger Causality/ block exogeneity wald test and found that during the crisis and period before the crisis, the variables were cointegrated but post-crisis there was no cointegration. They also found that there exists a dynamic relationship between the four variables under study, and the results prove that variables were highly affected by the US financial crisis of 2008. Ayele et al. (2017) examined the volatility of gold prices in Ethiopia using the Exponentially Weighted Moving Average and GARCH (2,2) models and found that the GARCH models give better results as compared to the EWMA model.

The paper also finds out that the price of Gold is influenced by interest rate, crude oil price and exchange rate volatility. Lamouchi & Badkook (2020) Studied the volatility of gold prices during some of the selected major events, including the stock market crash, terrorist attack, the Gulf War, the financial crisis and the health pandemic. The authors used generalized autoregressive conditional heteroskedasticity (GARCH) and T-GARCH models to test the volatility and found that during some of the crises, gold prices showed high volatility and significant persistence during others. So, it was concluded that the nature and characteristics of the crisis are very much relevant to the movement of gold prices in both spot and future markets. Beckmann et al. (2015) found that gold prices denominated in the US dollar gain value when the USD depreciates. They also found that the US dollar is the most important currency while forecasting the price of Gold all over the

world. A volatile US dollar makes way for Gold to be used as a strong hedging tool. (Apergis, 2013) Used daily and quarterly data to examine if gold price has a relationship with Australian Dollar exchange rates. They employed an error correction model (ECM) to determine the predictive ability of the variables under consideration. It was also found that there is enough evidence of gold prices forecasting the movement of Australian dollar/USD exchange rates. (Mishra, Das, & Mishra, 2010) Ran Granger causality and VECM tests to investigate any causality between stock market return and gold spot price in India and found that there exists a two-way causality between BSE 100 Index and gold Spot Prices in India.

Similarly, Samanta and Zadeh (2012) found the potential presence of co-movements among oil, Gold, dollar, and stock prices utilizing Vector Autoregression Moving-Average (VARMA), Granger causality, and Johansen cointegration. (Baur & McDermott (2010) Tested the safe-haven effect of Gold by considering 53 different countries from all over the world and applying the principal regression technique. The result shows that for developing countries' stock markets, such as Europe or the United States, Gold is a better hedge and a haven, but for emerging market economies such as BRICS, safe-haven properties could not be found. Baur D. G. (2012) Tested for asymmetric volatility of gold returns by applying ARCH, GARCH and GJR-GARCH models. The results show that the volatility of gold returns reacts asymmetrically towards positive and negative returns. The results are an extension to the previous paper that is the haven property of Gold.

Tripathy (2017) used monthly gold prices to predict the gold price in India and to check the predictive accuracy of the model using different forecasting techniques. The author found that ARIMA (0,1,1) is the best autoregressive model to predict gold prices in India. Using the Asymmetric power GARCH Model on the Gold spot and futures price data, Tully & Lucey (2007) prove that the US Dollar is the main and, most of the time, the only macroeconomic variable that can influence gold price return. Arfaoui & Rejeb (2017) Applied regression analysis to find the nature of the relation between gold Price, Oil Price, US Dollar and Stock Market and found that although all the variables are interrelated, Gold and Oil price have a negative relationship with the US Dollar and also found that when the stock market goes under a recession, it triggers demand for Gold to be used as safe-haven and increase gold prices.

Gokmenoglu & Fazlollahi (2015) Used the ARDL Cointegration and Error Correction Mechanism to check any long-run relationship among gold price volatility, Oil Price Volatility and the S&P500 market index and found that in both the long run and short run, gold prices have the highest impact on the S&P500 market index. Ewing & Malik (2013) Aim to investigate the volatility of gold and oil prices when structural breaks are incorporated into the model.

The authors used univariate and bivariate GARCH models for their examination and found a significant transmission of volatility between Gold and Oil prices. In their study, Bampinas & Panagiotidis (2015) investigated the causal relationships between crude oil and gold spot prices before and after the financial crisis. They previously observed a one-way causal relationship between oil and Gold. However, during the years following the crisis, they saw a bidirectional causal relationship. Choudhry et al. (2015) examined the nonlinear dynamic associations between gold returns, stock market returns, and stock market volatility in the UK and Japan during the global financial crisis. The findings indicate that Gold may not exhibit strong performance as a haven asset during periods of financial crisis.

Shahbaz et al. (2017) conducted a study to determine the ability of oil prices to predict gold prices. They used a unique nonparametric causality-in-quantiles testing approach and discovered compelling evidence that oil prices can accurately predict gold market volatility.

In a study conducted by Miyazaki and Hamori (2013), the researchers examined the cause-and-effect links between Gold and stock market performance or uncertainty. They used nonuniform weighted cross-correlations and discovered that there is a one-way causality in terms of average values from stock to Gold. However, they did not find any causality in terms of variability between the two. Zhang and Wei (2010) discovered consistent patterns between the price of crude oil and the price of Gold, demonstrating a substantial positive correlation through the use of

Cointegration and Granger causality testing. Similarly, Raza et al. (2018) investigated the correlation between economic policy uncertainty and gold prices through the utilization of the traditional linear Granger causality test and nonparametric causality-in-quantiles approach.

The findings emphasize that economic policy uncertainty has a significant impact on gold prices in all the nations analyzed, particularly in the lower percentiles. Ingalhalli, G., & Reddy (2016) employed Granger causality tests on crude oil prices, gold prices, Forex, and the stock market index. This paper found only unidirectional causality among the variables, where only the crude oil granger causes exchange rate and gold prices, and the Sensex granger causes fluctuations in crude oil price. In a similar study conducted by Jain & Biswal (2016), the DCC-GARCH model was employed to analyze the dynamic contemporaneous link among variables and to analyze the lead-lag linkages, symmetric and asymmetric nonlinear causality tests were conducted and found that fluctuations in Gold and oil price cause fluctuations in Indian currency value and Stock market index also.

Based on the findings of the literature review, it is evident that several research have examined the association between two or more variables. However, there is a limited number of studies that have specifically investigated the alterations in these associations during the COVID-19 pandemic. Moreover, there is a scarcity of research exploring this topic within the Indian setting. The significance of doing such a study is apparent within the framework of economic theory. This study is a fresh endeavour to examine the Cointegration and causal connection among the four variables in India during the COVID-19 economic crisis.

3. Data and Methodology

This study analyses the Closing Spot prices of Crude oil and Gold collected from the Multi Commodity Exchange (MCX) website, the closing value of Sensex collected from the Bombay Stock Exchange (BSE) website, and INR-USD reference rates collected from the Reserve Bank of India (RBI) website. The data set is divided into two subgroups, which are named the pre-COVID period and the COVID period. The data divide is on 11 March 2020, when the World Health Organization declared Covid-19 a pandemic. For this analysis, the pre-COVID period is considered to be from 1 January 2017 to 11 March 2020. Variables prior to 2017 are not considered to keep the effect of demonetization out of this analysis.

Since the Covid-19 pandemic is still not gone, the period for the Covid crisis is taken starting from 12 March 2020 to 30 July 2021. The analysis was done using STATA and Microsoft Excel. Observations having value for all four variables are included in the data set for this analysis. The raw dataset is non-stationary at levels. We have used natural logarithm first difference, which is also called return series, for all four variables to make the dataset stationary. The detailed results of the Augmented Dicky Fuller (ADF) test are shown in Table 3.

$$r = \ln\left(\frac{Pt}{P(t-1)}\right) * 100 \quad (1)$$

we have examined different properties of the data set for both periods by using descriptive statistical tests. Then, we checked for Cointegration among the variables by applying Johansen's cointegration test.

If the variables are found to be cointegrated, we employ VECM, or else we use a simple VAR model. To determine the appropriate lag to use in the model, we tested the Akaike Information Criterion (AIC) and Hannan-Quinn Information Criterion (HQIC).

3.1. Johansen's Cointegration Test

Cointegration refers to a linear relationship among two or more time series, which are individually non-stationary, but when they are combined, they become stationary. It is very much evident from the existing literature that Johansen's Cointegration test has been a dominant technique used by researchers to find Cointegration among variables (Narang & Singh, 2012; Samanta & Zadeh, 2011; Srivastava, 2010). The Vector Autoregressive (VAR) model equation for the cointegration test is as follows:

$$\Delta Y_t = \mu + \prod Y_{t-1} + \sum_{i=1}^{k-1} \tau_i \, \Delta Y_{t-1} + \epsilon_t \quad (2)$$

Johansen tests Cointegration using two likelihood ratios. Statistics include trace (λ_{trace}) and max eigenvalue (λ_{max}). In case of any conflict between λ_{trace} and λ_{max} statistics, employ trace statistics (Johansen & Juselius, 1990).

3.2. Vector Autoregression

The variables that are cointegrated have a long-term equilibrium relationship; however, in the short run, there may be disequilibrium. To find this disequilibrium, we employ the vector error correction mechanism where the error term represents the speed of adjustment to put the variable in disequilibrium back in the long-term equilibrium trajectory. However, when the variables are not cointegrated, we cannot use the VECM model. Rather, we need to run a Vector Autoregressive Model (VAR) model. The equation for the VAR model is as follows:

$$Y_t = \beta + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \varepsilon_t \quad (3)$$

where Y_t is the logarithmic return on the i_{th} index; X_t is the logarithmic return on investments in the other three assets; α and β are the structural parameters of the model; ε_{it} is the random component. The same analysis is carried out four times by taking each variable as a dependent variable one by one.

3.3. Granger Causality Test

And at last, to find out the direction of short-run causality among the variables, we employ the VAR Granger Causality test. The VAR equation for the Granger causality test is shown below:

$$\mathbf{Y_t} = \alpha_0 + \sum_{i=1}^{k} \mathbf{a_i} \mathbf{Y_{t-i}} + \sum_{j=1}^{k} \mathbf{b_j} \mathbf{X_{t-j}} + \varepsilon_t \quad (4)$$

Here, αj and βj are the regression coefficients, and εi is the error term. The test is based on the null hypothesis:

H_0: $\beta_1 = \beta_2 = \ldots = \beta_m = 0$

We say that x Granger causes y when the null hypothesis is rejected.

If the null hypothesis is rejected for equation (4), we may infer that X_t Granger-cause Y_t. The two variables exhibit a lead-lag connection, to put it otherwise. Likewise, the null hypothesis positing the absence of causality can be examined for other equations. Nevertheless, this test is not suitable when the provided series exhibit Cointegration. To analyze the short-run causality, it is recommended to utilize the Engle and Granger (1987) error correction—VEC Granger causality/Wald test in this scenario.

4. Empirical Results

The descriptive or summary statistics of the data shown in Table 1 clearly show that the standard deviation of all the variables has increased during the COVID period from the pre-COVID period, thereby indicating larger volatility in the returns of these variables. Return of Crude oil was the most volatile asset during the Covid period, with a standard deviation of 5.7758. Similarly, the standard deviation of the other three variables, namely Crude, Gold and Sensex, also rose during the Covid period. Interestingly, the average daily return of the stock market has increased during the COVID period, but for the other three variables, it has gone down along with becoming more volatile. This is basically because of anticipation of the opening of COVID-related restrictions and the wide participation of foreign investors in search of good returns in a developing and growing country like India. This has also stimulated many private companies to go public during this period for the expansion of their business. The correlation among the return series across both the sub-periods is shown in Table 2. In the pre-COVID period, the return of USD and Gold had a consistent negative relationship with the return of the stock market, but in the COVID period, USD bears a negative correlation with all the other three variables. However, the correlation between stock market return and gold return became positive during the Covid period. The first result is backed by various literature that indicates that USD and Gold are alternative investments to the stock market, but during the Covid period, the Indian market has basically moved in the same direction.

4.1. Augmented Dicker- Fuller Test

To employ Johansen's cointegration test, we must check for the stationarity of the data, and we have

used Augmented Dicky Fuller (ADF) test for this purpose. The ADF test found that all the variables are non-stationary at levels in trend and intercept, intercept and None form across the two sub-periods. The trend and intercept results can be seen in the table 3. However, when we take the return series of the variables, then all the variables (RUSD, RCRUDE, RGOLD, RSENSEX) become stationary. Theory and literature suggest that if any dataset is non-stationary at levels but stationary when taking the first difference, we can employ Johansen's cointegration test. As all four variables match this criterion, we have employed Johansen's test of Cointegration.

4.1. Johansen's Test of Cointegration

For the selection of appropriate lag length, we have used the Akaike Information Criterion (AIC) and the Hannan-Quinn Information Criterion (HQIC). Both AIC and HQIC suggest that the optimal lag length during the per-covid period is two, and during the COVID period, it is one. The result of Johansen's test of Cointegration is shown in Table 4, and it is very much evident from the results of both the trace and maximum eigenvalue statistics that the null hypothesis of no cointegrating relationship is accepted, which indicates there is no cointegrating relationship among the variables. Thus, from the results, we can conclude that in the long run, there are four variables that are not associated. The findings differ from the outcomes of the previous studies carried out by Singh & Sharma (2018) and Gokmenoglu & Fazlollahi (2015). So, in this situation, we cannot use VECM; rather, we have employed Vector Autoregression (VAR) and Granger Causality to see the short-term association of the variables.

4.2. Vector Autoregression

In Table 5, we can see that USD is affected by its own lags at 1 and 2 in the pre-COVID period; however, in the COVID period, along with its own lag, USD is also affected by the first lag of both Gold and Sensex. Hence, we can infer that during the Covid period, the USD reference rate was dependent on the price of Gold and Stock Market performance. Similarly, Crude oil price in the pre-covid times was affected by its own lags as well as the price of Gold at lag two and affected by Sensex and USD at both legs; however, in the COVID period, crude oil price was no longer dependent on Gold Price and USD. Gold price, on the other hand, was affected by the stock market and its own lag during the pre-COVID period, but the results do not show any impact of the stock market on Gold. From this result, we can say that Gold was no longer a safe investment asset during the Covid period.

Sensex is affected by its own lags, and USD and Gold are at lags 1 and 2 during the pre-COVID period, but during the Covid period, it is only affected by USD and its own lag. The findings are corroborated by prior research conducted by Beckmann et al. (2015) and Arfaoui & Rejeb (2017). Nevertheless, the findings observed during the COVID period contradict the concept of Gold's haven property as suggested by (Baur & McDermott (2010), but it supports the findings of Choudhry et al. (2015). The COVID-19 pandemic and resulting economic crisis have brought about significant structural changes in the economic system. The study provides evidence of a scenario in which the marker has deviated from established norms.

4.5. Granger Causality

Table 6 shows the result of the Granger causality Wald test to check for the direction of causality among the variables. We can see that in the pre-COVID period, there was unidirectional causality between USD and Sensex to the crude oil and bidirectional causality between Gold and Crude oil. However, in the COVID period, we can see a unidirectional causality between gold prices and USD and a bidirectional causality between USD and Sensex.

The results shown by the Granger Causality Wald test are similar to the results shown by the Vector Autoregression test, which makes our inference about the variables more robust and reliable. Considering the results of all the tests and analysis, we can say that the association between the USD reference rate, crude oil price, gold price and the stock market is very dynamic and in a developing country like India, it is further complicated when experiencing an uncertain situation like Covid- 19 pandemic. We can see only one consistent relationship between Crude oil price and the stock

Table 1
Descriptive Summary Statistics

	Pre-Covid Period				Covid Period			
Variable	LU	LC	LG	LS	LU	LC	LG	LS
Mean	4.221	8.260	10.368	10.464	4.306	8.119	10.770	10.648
Std. Dev.	0.044	0.149	0.107	0.105	0.014	0.353	0.075	0.186
Min	4.148	7.840	10.230	10.189	4.280	6.787	10.598	10.165
Max	4.309	8.626	10.691	10.644	4.341	8.632	10.933	10.881
Pr(Skewness)	0.358	0.764	0.000	0.000	0.012	0.000	0.000	0.000
Pr(Kurtosis)	0.000	0.000	0.434	0.000	0.000	0.000	0.903	0.000

Return Series

	Pre-Covid Period				Covid Period			
Variable	RUSD	RCRUDE	RGOLD	RSENSEX	RUSD	RCRUDE	RGOLD	RSENSEX
Mean	0.011	-0.047	0.058	0.038	0.002	0.226	0.031	0.115
Std. Dev.	0.347	2.119	0.632	0.809	0.319	5.775	1.048	1.900
Min	-1.535	-17.962	-2.286	-5.305	-1.318	-56.843	-3.090	-14.101
Max	1.374	14.541	3.662	5.185	1.186	34.704	12.748	11.573
Pr(Skewness)	0.314	0.000	0.000	0.000	0.467	0.000	0.000	0.000
Pr(Kurtosis)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2
Correlation Matrix

	Pre-Covid Period				Covid Period			
	RUSD	RCRUDE	RGOLD	RSENSEX	RUSD	RCRUDE	RGOLD	RSENSEX
RUSD	1.000				1.000			
RCRUDE	0.179	1.000			-0.087	1.000		
RGOLD	0.326	0.099	1.000		-0.022	0.051	1.000	
RSENSEX	-0.306	0.005	-0.198	1.000	-0.377	0.049	0.038	1.000

Table 3

	Pre covid		Post Covid	
Variable	Trend and Intercept	P Value	Trend and intercept	P value
Lu	-0.00089	0.75100	-0.02390	0.04600
LC	-0.00502	0.33000	-0.01180	0.18600
LG	0.00269	0.20700	-0.01210	0.11100
LS	-0.00731	0.00800	-0.00550	0.30900
RUSD	-1.02949	0.00000	-1.05970	0.00000
RCRUDE	-0.95752	0.00000	-1.03920	0.00000
RGOLD	-0.98318	0.00000	-.970710	0.00000
RSENSEX	-0.93364	0.00000	-1.18010	0.00000

Augmented Dicker- Fuller (ADF) Test Results

Table 4

Period	Rank	Eigen Value	Trace Statistic	5% Critical Value	Max Statistic	5% Critical Value
Pre-covid	r =0	.	38.53860*	47.21000	14.88870*	27.07000
	r≤ 1	0.01930	23.65000	29.68000	12.76240	20.97000
	r≤ 2	0.01657	10.88750	15.41000	10.83580	14.07000
	r≤ 3	0.01408	0.05170	3.76000	0.05170	3.76000
During covid	r =0	.	40.83650*	47.21000	22.73250*	27.07000
	r ≤ 1	0.06561	18.10400	29.68000	13.90940	20.97000
	r ≤ 2	0.04067	4.19460	15.41000	3.39770	14.07000
	r ≤ 3	0.01009	0.79700	3.76000	0.79700	3.76000

Johansen's Test of Cointegration Results

"*" *Indicates that the null hypothesis is accepted and there is 0 (zero) cointegrating relation among the variables.*

market during both sub-periods. In the pre-Covid era, there was a noticeable relationship between the price of Gold and factors such as crude oil and the Sensex. Similarly, the price of crude oil was granger caused by the USD reference rate, as well as Gold and the Sensex. These findings align with the outcomes presented by Ingalhalli, G., & Reddy (2016). However, the results are in contradiction to the findings of Mishra, Das, & Mishra (2010) who found two-way causality between Sensex and Gold.

5. Conclusion and Policy Implications

Various incidents in the past have created such situations in the financial market that the four variables under consideration, namely Gold Price, Crude oil Price, stock market and INR-USD reference rate, have seen volatile periods, and this characteristic prompts us to investigate the interrelation between the movements of the four time-series variables. The preliminary analysis using Johansen's test of Cointegration proves that there are no long-term relationships between the variables just before and during the covid-19 pandemic. When we employed Vector Autoregression to check for the short-run relationships among the variables, we found that though the gold price was affected by stock market movement in the pre-COVID period, during the COVID period, no such relationships could be found. The same goes with Crude oil prices; in the pre-COVID times, it was affected by gold prices, the USD reference rate and the movement of the stock market, but during COVID times, crude oil prices were no longer dependent on USD and Gold Prices. This dynamic relationship among the variables is further supported by the results of Granger causality tests, which go in tandem with the results of Vector Autoregression. From the findings of this study, the following conclusion can be made firstly, there exists a dynamic relationship between gold price, crude oil price, stock market and INR-USD reference rate, and at the time of a crisis like COVID-19, it becomes more difficult to predict their movements. Secondly, the safe-haven property of Gold was absent during the COVID-19 pandemic and subsequent economic crisis.

The findings of our study have important implications for investors and portfolio managers. Gold can be utilized as a hedge against portfolio risks associated with equities, crude oil, and exchange rate fluctuations in terms of returns. The ramifications are more significant in the pre-crisis period than in the period of the COVID-19 financial crisis.

However, there is enough scope for further research on this topic by taking a larger time horizon and by including some other important asset classes which can affect the given four variables. In this article, our primary focus is on the overall relationship between the variables.

Therefore, the results presented here are rather static and represent an average interpretation.

Table 5
Vector Autoregression (VAR) Results

	Dependent Variables							
Pre-Covid	USD		Crude		Gold		Sensex	
	Coefficient	P Value	Coefficient	P Value	Coefficient	P Value	Coefficient	P Value
USD (-1)	.921	.000***	.896	.000***	.003	.967	.213	.020**
USD (-2)	.066	.096*	-.926	.000***	.002	.976	-.209	.020**
Crude (-1)	.001	.831	.992	.000***	.013	.249	-.009	.537
Crude (-2)	.000	.943	-.001	.969	-.017	.140	.010	.461
Gold (-1)	.028	.169	.198	.113	1.020	.000***	-.095	.052*
Gold (-2)	-.027	.199	-.228	.069*	-.022	.554	.095	.053*
Sen (-1)	-.021	.187	.524	.000***	.062	.037**	1.069	.000***
Sen (-2)	.024	.131	-.490	.000***	-.055	.063*	-.079	.040**
	Covid-Period Analysis							
USD (-1)	.936	.000***	.380	.234	.075	.198	.179	.080*
Crude (-1)	.001	.113	.921	.000***	.005	.173	.003	.601
Gold (-1)	-.005	.003**	.027	.549	.989	.000***	.019	.196
Sen (-1)	-.005	.014**	.156	.000***	-.006	.447	.995	.000***

, ** and * indicates significant results at 10%, 5% and 1% level of significance respectively.*

Table 6
Granger Causality/ Wald Test Results

	Pre-Covid Period		Covid Period	
Null Hypothesis	$\chi 2$ value	Probability	$\chi 2$ value	Probability
Crude does not Granger-cause USD	2.375	0.305	2.5112	0.113
Gold does not Granger-cause USD	2.592	0.273	4.5858	0.032**
Sensex does not Granger-cause USD	4.085	0.130	5.9838	0.014**
USD does not Granger-cause Crude	16.24	0.000***	1.4193	0.234
Gold does not Granger-cause Crude	8.034	0.018**	.35828	0.549
Sensex does not Granger-cause Crude	35.15	0.000***	12.865	0.000***
USD does not Granger-cause Gold	.3933	0.821	1.6578	0.198
Crude does not Granger-cause Gold	4.787	0.091*	1.8585	0.173
Sensex does not Granger-cause Gold	7.018	0.030**	.57894	0.447
USD does not Granger-cause Sensex	5.255	0.072*	3.0129	0.083*
Crude does not Granger-cause Sensex	.8784	0.645	.27306	0.601
Gold does not Granger-cause Sensex	3.763	0.152	1.6726	0.196

, ** and * indicates significant results at 10%, 5% and 1% level of significance respectively.*

However, future research can explore the dynamic and time-varying nature of their interaction. This work provides insights into their relationship from a mean standpoint. However, it is important to include other views in future research, such as volatility and risk spillover.

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