“Modelling volatility effects between stock, oil, gold and forex markets: Evidence from India”

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ARTICLE INFO	Varsha Ingalhalli and Prachi Kolamker (2023). Modelling volatility effects between stock, oil, gold and forex markets: Evidence from India. *Investment Management and Financial Innovations*, *20*(2), 53-65. doi:10.21511/imfi.20(2).2023.05
DOI	http://dx.doi.org/10.21511/imfi.20(2).2023.05
RELEASED ON	Friday, 14 April 2023
RECEIVED ON	Tuesday, 07 February 2023
ACCEPTED ON	Monday, 03 April 2023

JOURNAL	"Investment Management and Financial Innovations"
ISSN PRINT	1810-4967
ISSN ONLINE	1812-9358
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
49	0	3

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

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MODELLING VOLATILITY EFFECTS BETWEEN STOCK, OIL, GOLD AND FOREX MARKETS: EVIDENCE FROM INDIA

Abstract

Although several studies on the integration of diverse stock markets have been conducted in the financial literature, most of them have focused on the integration and volatility spillovers across established stock markets. The present study explores the dynamics of integration and volatility spillover across gold, oil, forex, and stock markets during four significant events in India: the pre-changed government regime, the post-changed government regime, the post-Brexit referendum date, and the COVID era. Daily data from 2010 to 2022 is divided into four categories using the Chow test. This is done to examine if these events' financial turmoil affects market interconnectivity. The unit root test determines data stationarity. The ARCH LM test examines series volatility clustering, and the BEKK GARCH test examines market volatility spillover. Results indicate that gold cannot be considered a hedge or safe haven. Secondly, market interconnectedness increased during the crisis period. Third, domestic political and geopolitical conditions globally do not increase the scale of spillover amongst financial assets, though they impact the spillover's magnitude. The results of this study have several important implications for portfolio diversification and risk management.

Keywords foreign exchange, gold, oil, stocks, volatility, market interconnectedness, BEKK-GARCH

JEL Classification E44, G01, G11

Received on: 7th of February, 2023
Accepted on: 3rd of April, 2023
Published on: 14th of April, 2023

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Conflict of interest statement:
Author(s) reported no conflict of interest

INTRODUCTION

Market integration is a phenomenon where various markets move in tandem and predict a similar trend (Chen et al., 2002). Prior research indicates that market interconnection increases during a crisis or significant economic, geopolitical or social events (Choudhry & Jayasekera, 2014; Jawadi et al., 2015; Jebran et al., 2017). As a result, risk mitigation by including various asset classes in a portfolio has become critical for investors.

The subprime mortgage crisis is a classic example that led to disruption in the US market and other developed and emerging markets across the globe (Zhou et al., 2012). Compared to other countries, Indian stock markets were unscathed by the volatility transmission from the US stock markets. In comparison to other markets, Indian stock markets were viewed to be highly efficient. According to studies, Indian markets are the sanest in terms of market risk (Chiang et al., 2013). The Indian financial markets have witnessed many global and country-level shocks in the past decade. The first was in 2014, wherein a decade-old ruling government regime was changed. In 2016 due to the United Kingdom's Brexit referendum, followed by the unprecedented COVID-19 pandemic, which led to the first lockdown in March 2020. The latest is the Russia – Ukraine war that hit on February 24, 2022, putting India's position in jeopardy as there is a direct impact on imports, thus affecting the rupee exchange rate.

When one market is disrupted, the negative impacts are rapidly transferred to other markets, which can cascade financial instability throughout the system. Although several studies on the integration of diverse stock markets have been conducted in the financial literature, most of these studies have focused on the integration and volatility spillovers across established stock markets. However, it is challenging to find a study of how significant global and macroeconomic events affect Indian asset classes. Over the past few decades, the Indian stock market's value and volume have grown significantly, providing market participants with a wide choice of investment options. India is the fifth largest economy in the world. Secondly, India is the fifth biggest equity market in market capitalization. Thirdly the solid economic growth has made the country attractive for investments. India has witnessed a substantial capital inflow in light of globalization and liberalization, making it an appropriate market to undertake the study. The primary contribution of this study is to explore the volatility transmission between the gold, forex, oil, and stock markets, taking into account the impact of significant events during the post-2008 subprime financial crisis in the United States. The markets considered under the study are the stock market, foreign exchange market, gold market, and oil market. The interconnectedness of various markets has become a vital element in portfolio decision-making. In this study, this issue is explored in a longitudinal study considering the four Indian financial markets.

1. LITERATURE REVIEW

Over the past decade, global and country-level events have increased uncertainty and volatility in financial markets. The global financial crisis of 2008, the Eurozone debt crisis of 2010–2012, the COVID-19 pandemic crisis, oil crises, and Brexit on a worldwide scale have demonstrated that interconnectedness between assets and financial markets is essential during crises and has the potential to trigger systemic risk episodes (Laborda & Olmo, 2021). This section explores the interrelationships between the four financial markets of oil, stocks, currency, and gold.

Markowitz's (1952) portfolio theory advises that individuals should diversify their assets and portfolios depending on risk-reward relationships. Investors have to invest their funds into investments that offer better-predicted returns for the level of risk they are willing to take. According to this theory, the assets that make up a diversified portfolio should not correlate with one another (Habiba et al., 2020). By doing so, the risk of investment can be decreased, and the possibility of profit can be increased. The Markowitz portfolio theory prompted many researchers and stakeholders to investigate global stock market links. Investors can benefit from diversifying their assets by understanding the connections between various financial markets. If two markets are correlated, then shocks in either market can affect the other. For example, the worldwide financial crisis, which took place in 2007-08, did not just affect the market in which it originated; instead, it quickly extended to other nations worldwide (Kumar, 2013).

Changes in stock prices, oil prices, gold prices, and currency rates all impact investor sentiments. As a result, the market experiences significant volatility and unpredictability (Padungsaksawasdi, 2020). In recent years, much focus has been on the connection between stock prices, oil prices, gold prices, and exchange rate prices (Sheikh et al., 2020; Singh & Sharma, 2018). There has been circumstantial evidence to suggest that instabilities in the price of crude oil could trigger an economic depression (Nguyen et al., 2020; Erten & Ocampo, 2021).

On the contrary, to the economy, stability, growth, and development, gold plays myriad roles in all of these areas. Gold continues to be a matter of interest to the literary and business worlds as it has a long history of use as a currency and an essential asset in the capital market. Numerous studies and research have been conducted, concentrating not only on its price but also on its impact on the foreign exchange rate and capital market. Melvin and Sultan (1990) concluded that the price of oil and the level of political stability are significant factors in determining the degree to which gold prices fluctuate. Following an examination of weekly gold prices, Capie et al. (2005) found that gold might be used as a hedge against variations in

http://dx.doi.org/10.21511/imfi.20(2).2023.05

the value of the US dollar to other currencies. Contrary to Reboredo (2013), gold cannot be a safe haven for investors when oil prices fluctuate. Baur and McDermott (2010) explored the importance of gold as a safe haven. They found that it serves as a hedge for the European and American markets rather than for the markets in emerging economies. Raza et al. (2016) considered the effects of the volatility of gold and oil prices on the stock markets of emerging nations. They discovered that the volatility of gold and oil prices has an inverse impact on the volatility of equity markets.

Golub (1983) and Krugman (1983) were the first to show the relationship between the price of oil and currency exchange rates. These authors made compelling cases for why changes in the price of oil should have an impact on currency exchange rates. Golub (1983) argues that since oil price is expressed in US dollars, a rise in oil prices will result in a surge in demand for US dollars. On the other hand, Krugman's (1983) analysis is predicated on the hypothesis that there is a link between the portfolio investment preferences of oil exporters and fluctuations in exchange rates. Indeed, as oil prices continue to rise, oil exporters will have more opportunities to diversify their investment portfolios. According to Krugman's (1983) analysis, changes in the current account are the primary determinant of currency exchange rate fluctuations. If a country's current account struggles due to higher oil prices, currency exchange rates will likely become less favorable. The previous research (Allegret et al., 2015; Rastogi et al., 2021) provides more recent evidence regarding this effect. According to the findings of Sadorsky (2000), currency exchange rates affect the price of oil.

Additionally, Akram (2009) discovered that a feeble dollar increases commodity prices. Previous studies revealed a causal relationship between the USD and the price of oil that goes in both directions (Fratzscher et al., 2014; Singhal et al., 2021). Arfaoui and Rejeb (2017) found that direct and indirect channels significantly differ in how well the message gets through. For example, they find that the stock market has no direct effect on oil prices. However, shocks to interest rates and risk significantly impact oil prices. In the same way, shocks have stronger effects on the price of oil and the US dollar than their direct effects. This result is important because it shows that shocks to financial markets don't have a one-way impact on oil prices and aren't limited to individual asset prices. Instead, the process is complicated and often happens indirectly through third-party asset markets.

In recent years, a growing number of studies have identified substantial correlations between crude oil prices and stock market performance (Kumar & Maheswaran, 2013; Sahu et al., 2014; Ghosh & Kanjilal, 2016; Sarwar et al., 2020). Kumar and Maheswaran (2013) estimated how crude oil prices affect different parts of the Indian market in terms of return and volatility. The author found that the crude oil price and the Indian industrial sector had a high conditional correlation, which was at its highest point during the global financial crisis of 2008–2009. Between 2000 and 2008, the influence of oil prices on the Vietnamese stock market was examined by Narayan and Narayan (2010). They discovered a positive and significant relationship between oil prices and stock returns. On the contrary, Jones and Kaul (1996) concluded that stock markets in the United States, Canada, Japan, and the United Kingdom are inversely correlated with crude oil prices. Using the GARCH-M model, a study was conducted by Valadkhani et al. (2009) on the Thai stock market and its dynamic relationship with several significant macroeconomic factors. The analysis revealed a negative link between the price of crude oil and the Thai stock market index. According to the findings of Filis (2010), the price of crude oil has an adverse effect on the stock market in Greece. Basher et al. (2012) concluded that a negative association exists between the crude oil market and the equity market.

Krugman (1983) examines long-term and short-term effects of the oil price shock on the U.S., Germany, and OPEC nations. According to this study, oil price shocks substantially affect key variables in these countries. Anoruo (2011) provides evidence of bidirectional causality between the varying prices of crude oil and stock market returns in the United States. Similarly,

Hosseini et al. (2011) conclude that there is a robust long-term and short-term link between oil price shocks and stock market performance. Chittedi (2012) investigates the long-term relationship between oil prices and stock prices in India from April 2000 to June 2011. Raheman et al. (2012) studied the relationship between oil prices and stock returns in Asia-Pacific nations and observed a significant short-run relationship. There is a significant and strong long-term relationship between stock market indexes and oil prices (Sahu et al., 2014). On the other hand, Sehgal and Kapur (2012) do not support the notion that oil price shocks significantly impact stock returns. Yadav et al. (2020) conclude that although crude oil prices have a strong short-term causal impact on the Sensex, there is no long-term association between them and the Indian equity market.

From the above-cited works, it has been understood that there is a linkage between the financial markets. However, the question here arises: What is the level of volatility spillover, and does the magnitude vary during the different events or crises? The present study contributes to the literature on how the different financial markets respond to the major political, socio or economic events occurring at the global and national levels. Thus, helping investors, policymakers, government, and portfolio managers adopt their future investment strategies.

2. METHOD

The study investigates volatility transmissions among India's oil, gold, foreign exchange, and stock markets. Daily data from 31/03/2010 to 31/03/2022 were used, which covers several periods that caused economic instability and changed the way markets behaved. The data for stock prices were obtained from the NSE website; exchange rate data was extracted from the RBI website, whereas gold and oil prices data were taken from the MCX website. The study is divided into four periods: pre-changed government regime, post-changed government regime, post-Brexit referendum date and the COVID period. The study uses the Nifty 50 index to represent the Indian Stock market, gold spot prices and oil spot prices from MCX, and the rupee-dollar exchange rate from the Reserve Bank of India website. The study takes natural logarithms of the prices. To analyze the data, the study employs the Chow test to validate the breakpoints followed by descriptive statistics to understand the features of the data and the ADF test to check for stationarity of the data. Also, the study uses the ARCH-LM test, a pre-requite test to validate the use of GARCH models. Since the ARCH-LM test is significant it suggests the presence of ARCH effects in the series, hence, justifying the use of GARCH models. To examine the volatility interdependence among the stock market, foreign exchange market, gold market, and oil market, the study proposes to use the BEKK-GARCH model. The BEKK-GARCH model was initially penned by Baba et al. (1990) and further established by Engle and Kroner (1995). Only for the third period, the study uses a multivariate GARCH model with asymmetric BEKK parameters constructed. As for the remaining periods, the asymmetric BEKK specifications were invalid, i.e. convergence was not achieved. In other words, negative news from own/other markets will have more significant influence during the third period than positive news. Unlike other times when the impact of positive or negative information is equivalent, there is a significant difference during this period.

The model permits interactions between conditional variance and covariance, which results in the generation of positive conditional covariance and a significant parameter reduction in the estimation.

$$H_t = C'C + A'\varepsilon_{t-1} \cdot \varepsilon'_{t-1}A + B'H_{t-1}B, \qquad (1)$$

where H_t represents the conditional variance and covariance matrix and is a function of lagged error terms and lagged conditional variance – the model for the four-variate GARCH model with covariance matrix where C is a 2X2 upper triangular matrix. The matrix represents the ARCH effect of volatility, ij indicates the impact of shock/news of market i on the volatility of market j. On the contrary, matrix B indicates the GARCH effects of volatility. B_{ij} represents the volatility spillover from market i to market j.

http://dx.doi.org/10.21511/imfi.20(2).2023.05

$$\begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} & h_{14,t} \\ h_{21,t} & h_{22,t} & h_{23,t} & h_{24,t} \\ h_{31,t} & h_{32,t} & h_{33,t} & h_{34,t} \\ h_{41,t} & h_{42,t} & h_{43,t} & h_{44,t} \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{bmatrix}' \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{bmatrix} +$$

$$\begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} \end{bmatrix}' \begin{bmatrix} \varepsilon^2_{(1,t-1)} & \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon_{1,t-1}\varepsilon_{3,t-1} & \varepsilon_{1,t-1}\varepsilon_{4,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon^2_{(2,t-1)} & \varepsilon_{2,t-1}\varepsilon_{3,t-1} & \varepsilon_{2,t-1}\varepsilon_{4,t-1} \\ \varepsilon_{3,t-1}\varepsilon_{1,t-1} & \varepsilon_{3,t-1}\varepsilon_{2,t-1} & \varepsilon^2_{(3,t-1)} & \varepsilon_{3,t-1}\varepsilon_{4,t-1} \\ \varepsilon_{4,t-1}\varepsilon_{1,t-1} & \varepsilon_{4,t-1}\varepsilon_{2,t-1} & \varepsilon_{4,t-1}\varepsilon_{3,t-1} & \varepsilon^2_{(4,t-1)} \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} \end{bmatrix} + \quad (2)$$

$$\begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} & h_{14,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{23,t-1} & h_{24,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} & h_{34,t-1} \\ h_{41,t-1} & h_{42,t-1} & h_{43,t-1} & h_{44,t-1} \end{bmatrix} \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} \end{bmatrix}.$$

In the case of the asymmetric BEKK GARCH model, the equation includes one more parameter represented by D. The equation is as follows;

$$H_t = C'C + A'\varepsilon_{t-1} \cdot \varepsilon'_{t-1}A + B'H_{t-1}B + \\ + D'\xi'_{t-1} \cdot \xi_{t-1}D, \quad (3)$$

Here, all the parameters are as explained before except D, where ξ_{t-1}, is coded as 1 in case of negative values and 0 otherwise, which displays the impact of negative shocks on conditional volatility. According to equation (2), the conditional variance of each market is a function of lagged error terms, lagged conditional variance and lagged shocks from bad news from all four markets. The elements of matrix D measure the impact of past negative shocks of market i on the current conditional volatility of market *j*.

3. RESULTS

Table 1. Chow test results

Breakpoints	*F*-statistic	Prob.
26/5/2014	582.528	0.00
23/6/2016	1218.857	0.00
20/3/2020	1216.101	0.00

The results of the Chow test were used to statistically validate the data breakpoints, as shown in Table 1. These breakpoints are used to divide the study period into four distinct phases. The first breakpoint was on May 26, 2014, when India's new government took office. After a decade of the previous government's rule, the democratic citizens of India voted for a change in government, which had a significant impact on the stock market. On June 23, 2016, the United Kingdom's European Union referendum, also known as the Brexit referendum or EU referendum, was held. The majority of votes cast were in favor of the United Kingdom leaving the European Union. The third breakpoint is the first coronavirus-induced lockdown in India. The lockdown was announced on the evening of March 19, 2020, when stock exchanges and other financial markets were shuttered. The investors' sentiments upon learning of the Prime Minister's decision were carried forward to the next trading day, i.e., March 20, 2020. The study, therefore, chose March 20, 2020 as the third breakpoint. The lockdown period has had a significant influence on the financial markets in India. In addition, all the breakpoints above affected individual markets and the transmissions between financial markets. This study aims to comprehend the volatility transmission between the four markets, i.e. stocks, foreign currencies, gold, and oil markets, over the four periods delineated by the breakpoints.

The first period, i.e., after the global financial crisis of 2008 and before the change in the government, was marked by an all-time high current account deficit, a depreciating rupee to the dollar exchange rate, numerous scams such as the 2G and coal scams, a surging inflation rate, and a reduction in public savings. The post characterizes the second period as taking government change before the Brexit referendum and the third period as occurring after the Brexit referendum and during the early stages of the COVID-19 pandemic. The

fourth period is considered to be the phase defined by the announcement of three lockdowns by the government of India, a vaccination effort, and the economic recovery from the pandemic.

Table 2 provides descriptive statistics on gold, oil, forex, and stock market log prices. For period 1, gold data is significantly negatively skewed, oil market data is slightly negatively skewed and nifty and forex market data is positively skewed. Similarly, in the case of period 2, the gold market was positively skewed. In contrast, the stock, foreign exchange, and oil markets were negatively skewed. Period 03 reveals negative skewness for the stock and oil markets, positive skewness for gold and less positive skewness for forex markets. Furthermore, period 4 showed negative skewness in the case of three markets, i.e., gold, stock, and oil markets, whereas positive skewness in the case of the Forex market. The kurtosis value presented in Table 2 indicates peaked leptokurtic data showing normal distribution. This is also supported by the results of the Jarque-Bera test, which rejects the null hypothesis of normality for all markets studied over the four time periods except the stock market in period 1. The null hypothesis is rejected at a 1% significance level. These preliminary descriptive statistics demonstrate significant asymmetry and excess kurtosis. Thus, justifying the use of GARCH family models.

Table 2. Descriptive statistics

	Mean	Median	Max	Min	Std. Dev	Skewness
Period 01						
LGOLD	10.2	10.23	10.4	7.98	0.2	–1.83
LNIFTY	8.62	8.61	8.9	8.39	0.09	0.15
LOIL	8.48	8.51	8.93	8.06	0.19	–0.16
LUSD	3.95	3.97	4.22	3.78	0.12	0.15
Period 02						
LGOLD	10.2	10.2	10.3	10.1	0.05	0.43
LNIFTY	9	9	9.1	8.86	0.05	–0.24
LOIL	8.15	8.08	8.77	5.95	0.33	–0.12
LUSD	4.16	4.15	4.23	4.07	0.04	–0.06
Period 03						
LGOLD	10.4	10.33	10.7	10.2	0.11	1.22
LNIFTY	9.26	9.29	9.43	8.95	0.11	–0.65
LOIL	8.22	8.23	8.63	7.23	0.17	–0.35
LUSD	4.22	4.22	4.33	4.15	0.04	0.08
Period 04						
LGOLD	10.8	10.78	10.9	10.6	0.06	–0.89
LNIFTY	9.56	9.61	9.84	8.95	0.22	–0.63
LOIL	8.32	8.42	9.16	6.79	0.4	–0.79
LUSD	4.31	4.31	4.34	4.28	0.01	0.15

	Kurtosis	J–B test	Prob	ADF	ARCH	Obs
Period 01						
LGOLD	14.72	6327.7	0	–1.3	48349.2	1006
LNIFTY	2.98	3.57	0.17	–2.1	8423.84	1006
LOIL	2.18	32.33	0	–0.7	32039.2	1006
LUSD	1.71	73.52	0	–0.9	118165	1006
Period 02						
LGOLD	2.57	18.95	0	–1.9	6594.84	500
LNIFTY	2.46	11.1	0	–0.9	8281.47	500
LOIL	5.78	162.2	0	–2.6	5440.34	500
LUSD	1.78	31.39	0	–2.6	18516.1	500
Period 03						
LGOLD	3.51	228.36	0	–1	22275.8	888
LNIFTY	2.37	78.18	0	0.86	111388	888
LOIL	4.18	69.61	0	–1.9	34052.8	888
LUSD	1.85	50.25	0	0	68380.7	888
Period 04						
LGOLD	4.11	89.33	0	0.19	16068.1	489
LNIFTY	2.24	44.35	0	–2.4	6673.91	489
LOIL	3.99	71.27	0	–2.2	16780.3	489
LUSD	2.23	14.03	0	–2.4	4641.07	489

Note(s): *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * indicates significance at the 10% level.

According to the ADF test, the price series log data are stationary at a 5% significance level for all periods in the study. Similarly, the null hypothesis of no ARCH effects is rejected. Presence of ARCH effects indicate that the volatility can be perfectly captured using the GARCH-BEKK model to understand the market volatility transmission.

The study's main objective is to examine cross-market spillover effects during four significant periods using the Full-BEKK GARCH model. The study adopts the BEKK methodology to analyze the dynamics of conditional volatility with interlinkages among the four markets. The model is best suited to analyze conditional variances and covariances interaction of several time series by examining the transmission of volatility. The full-BEKK model encapsulates cross-market effects, namely shock and volatility spillovers. One significant advantage of the BEKK model is that H_{ij} Is positive definite if the diagonal elements of C, A, and B are positive and significant. The conditional variance function of each market is determined by the past error and conditional variance of the four markets. The results provided in table 3, the stock market is represented by 1, the foreign exchange market as 2, the gold market as 3, and the oil market as 4.

http://dx.doi.org/10.21511/imfi.20(2).2023.05

Table 3. Results of the BEKK–GARCH model

Variable	Period 1	Period 2	Period 3	Period 4
	Coeff	Coeff	Coeff	Coeff
C(1,1)	0.009*	0.009*	0.006*	0.008*
C(2,1)	−0.001*	−0.001*	−0.000*	−0.000*
C(2,2)	0.005*	0.002*	0.002*	0.002*
C(3,1)	0.001**	−0.001**	−0.001*	−0.001*
C(3,2)	0.001**	−0.000	0.001*	0.001**
C(3,3)	−0.008*	−0.007*	0.005*	0.006*
C(4,1)	−0.000	0.001	0.001	0.003**
C(4,2)	−0.005*	−0.000	−0.002**	−0.001
C(4,3)	−0.002*	−0.009*	0.001	−0.00223
C(4,4)	−0.015*	0.019*	0.013*	−0.023*
A(1,1)	0.984*	0.977*	0.974*	0.919*
A(1,2)	−0.008*	0.005	−0.011*	−0.007*
A(1,3)	−0.016**	−0.018***	0.000	0.016**
A(1,4)	−0.000	−0.022	0.029	−0.021
A(2,1)	0.013**	−0.011	−0.027**	−0.009
A(2,2)	0.980**	0.996*	0.986*	0.917*
A(2,3)	−0.010	−0.022	−0.004	0.105*
A(2,4)	0.029**	−0.133	0.012	0.015
A(3,1)	−0.007**	0.012	−0.004	−0.005
A(3,2)	−0.001	−0.004	−0.001	−0.002
A(3,3)	0.979**	0.967*	0.987*	0.965*
A(3,4)	−0.005	0.076**	0.004	0.046***
A(4,1)	−0.008**	−0.001	0.001	−0.002
A(4,2)	0.002	0.000	0.002***	0.002*
A(4,3)	−0.001	−0.004**	0.000	−0.001
A(4,4)	0.973**	0.975*	0.988*	0.985*
B(1,1)	0.094*	0.127*	0.117*	−0.344*
B(1,2)	−0.006	−0.029*	−0.006	0.000
B(1,3)	−0.091**	−0.002	0.018	0.049*
B(1,4)	−0.054*	−0.003	−0.112*	−0.154*
B(2,1)	−0.033*	−0.019	−0.022	0.104
B(2,2)	0.044	0.058	0.070*	−0.274*
B(2,3)	−0.042*	0.025	0.032**	0.274*
B(2,4)	−0.143*	0.468*	0.088	−0.722*
B(3,1)	0.005	−0.020	0.007	−0.047*
B(3,2)	−0.013***	0.015**	−0.004	0.008**
B(3,3)	0.050	0.168*	0.018	−0.247*
B(3,4)	−0.004	−0.180*	0.057**	0.091**
B(4,1)	−0.019**	−0.001	−0.011*	7.43E−05
B(4,2)	−0.005	−0.005*	0.005*	−0.000
B(4,3)	−0.026*	0.005	−0.007**	−0.012**
B(4,4)	0.066**	0.150*	0.035	−0.128*
D(1,1)			0.022	
D(1,2)			0.015*	
D(1,3)			0.035*	
D(1,4)			0.131*	
D(2,1)			−0.155*	
D(2,2)			0.051	
D(2,3)			0.074**	
D(2,4)			−0.464*	
D(3,1)			−0.050	
D(3,2)			0.024***	
D(3,3)			−0.010	
D(3,4)			0.235*	
D(4,1)			0.022*	
D(4,2)			−0.002	
D(4,3)			0.019*	
D(4,4)			0.130*	

Note(s): *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level. The sample period is from March 31, 2010 to March 31, 2022. Period 1 is from 31/03/2010 to 25/05/2014, Period 2 is from 26/05/2014 to 22/06/2016, Period 3 is from 23/06/2016 to 19/03/2020, and Period 4 is from 20/03/2020 to 31/03/2022.

3.1. Period 01: Post-global financial crisis, 2008

The evidence of positive and significant ARCH effects (A11, A22, A33, and A44) reveals the impact of past shocks and news on the current conditional variance of all four markets. Also, positive and significant GARCH effects (B11 and B44) indicate the impact of past conditional variance on the current conditional variance of the stock market and foreign exchange market, respectively. Each market's current conditional variance is affected by its own past shocks, news, or variances and spillovers from other markets. The stock market's current conditional variance is affected by shocks, news, and volatility spillovers from the foreign exchange and oil markets. It is also affected by past shocks and news spillovers from the gold market. In the case of the foreign exchange market, its current conditional variance is affected by past shocks/news from the stock market and volatility spillover from the gold market. The gold market's current conditional variance is affected by past shocks and volatility spillover from the stock market. It is also affected by volatility spillover from oil and foreign exchange market. The oil market is affected by past shocks and news spillover from the foreign exchange market and volatility spillover from the stock market and foreign exchange market.

In other words, the strong ARCH effects compared to GARCH effects reveal that the markets are volatile to past shocks/news compared to volatility spillovers, exhibiting short-term volatility persistence. The findings demonstrate bi-directional volatility spillover between stock and oil markets, as well as the forex and gold markets. Whereas, unidirectional volatility spillover is found from

the stock market to the gold market, foreign exchange market to the oil market, and from the oil market to the gold market. The results confirmed and supported the previous studies (Vardar et al., 2018; Gunay & Can, 2022; Katusiime, 2018), which revealed increased volatility spillover among the markets, especially during times of turmoil.

3.2. Period 02: Post-government change in India

As noted in Table 3, the estimated ARCH coefficients of all the markets (A11, A22, A33, and A44) and GARCH coefficients of stocks, gold, and oil markets (B11, B33, and B44) are statistically significant. This shows that the conditional variances of the markets are affected by their own lagged shocks and news and their own lagged conditional variance. Moreover, the reported ARCH coefficients are stronger than the GARCH coefficients. This suggests that the conditional volatility of corresponding markets changes rapidly to their own recent lagged shocks/news compared to their past conditional volatility. With the statistically significant off-diagonal coefficients in matrices A and B of the BEKK conditional variance model, the volatility transmission among the markets can be examined. The results show lagged shocks or news spillovers from the stock market and oil market to the gold market and from the gold market to the oil market. Hence, evidencing bidirectional shock/news spillover between the oil market and the gold market and unidirectional spillover from the stock market to the gold market. Unidirectional volatility was observed from the stock market and gold market to the foreign exchange market and from the gold market to the oil market. However, bidirectional volatility spillover was evinced between the foreign exchange market and the oil market. During this period, the markets witnessed more volatility spillovers than shock spillovers, even though the magnitude of volatility spillover is less compared to shock/news spillovers. In other words, the markets are interlinked mainly due to volatility spillover rather than shock/news spillover.

3.3. Period 03: Post-Brexit Referendum date

The BEKK model with asymmetric effects holds, i.e. convergence is achieved, where negative news creates more volatility than positive news. The positive and significant ARCH effects (A11, A22, A33, and A44) point out that the conditional variances of all four markets are significantly affected by their own lagged shocks and news, and only in the case of the stock market and foreign exchange markets (B11 and B22), their conditional variances are affected by their own lagged conditional variance. The four markets are interlinked through ARCH and GARCH spillovers. These spillovers are captured by the off-diagonal elements in matrices A and B of the conditional variance equation estimated using the BEKK model. Results evinced bidirectional shocks and news spillover between the stock market and foreign exchange market. At the same time, unidirectional shock/news spillover was noticed from the oil market to the foreign exchange market. Regarding the volatility spillover among the markets, we observe bidirectional spillover effects between oil and gold markets and oil and stock markets. In contrast, unidirectional spillover was evidenced from the oil market and gold market to the foreign exchange market. The asymmetric effects reveal that negative shocks or news increase the volatility in the corresponding market as compared to positive news. The results point out that the foreign exchange market is extensively impacted by negative shocks and news from gold and the stock market. However, the stock market is majorly affected by negative shocks/news from the oil market. In the case of the gold market, negative shocks or news from the oil market, stock market, or foreign exchange market increase the volatility compared to any positive news. The oil market, on the other hand, is impacted majorly by negative shocks/news from gold and the stock market.

3.4. Period 04: Covid-19 period

The markets in this period are closely interlinked, and the ARCH effects are stronger than the GARCH effects, indicating the market's behaviour, where lagged shocks or news have more impact than any lagged volatility fluctuations. However, volatility spillover is more common in the markets than shock or news spillover. Significant ARCH effects A11, A22, A33, and A44 signal the impact of lagged shocks or news from their own market on the current volatility of all four markets. Significant B11, B22, B33, and B44 show the effect of own lagged conditional variance on vola-

http://dx.doi.org/10.21511/imfi.20(2).2023.05

tility. The off-diagonal elements of matrix A reveal the lagged shock/news spillover effect among the markets. The volatility changes in the foreign exchange market are significantly caused by shocks and news spillover from the stock and oil markets. In the case of the gold market, the shocks/news from the foreign exchange market and the stock market. Moreover, the oil market is affected by lagged shocks/news only by the gold market. On the contrary, shocks or news from other markets doesn't impact the stock market's volatility. The off-diagonal elements of matrix B displayed bi-directional lagged volatility spillover on the current conditional variance between foreign exchange and gold market, oil market and gold market, and the stock market and gold market. In the case of the oil and stock markets, however, there was unidirectional lagged volatility spillover from the stock market to the oil market. A similar scenario was observed in the case of the oil market and the foreign exchange market, where a unidirectional lag volatility spillover was observed running from the foreign exchange market to the oil market.

4. DISCUSSION

Current stock market volatility is driven by its own lagged shocks and news and lagged conditional variances for all four time periods. Similarly, the oil market's current conditional variance is affected by its own lagged shocks and lagged conditional variance for the three periods, with the exception of period three, i.e. post-Brexit referendum, where it is affected by its own lagged shocks and news, and negative news has a significant impact on the volatility, whereas its own past volatility had no effect on its current volatility. In the case of the gold market, its current conditional variance is affected by its own lagged shocks/news and its own lagged conditional variance in the second period, which is characterized by post-government change and pre-Brexit referendum, and the fourth period, which was characterized by developments from the pandemic in India and globally which affected the Indian markets directly, which led to affecting the transmissions among the Indian markets. In periods one and three, the conditional variance of the gold market is only affected by its own lagged shocks and news. The current conditional variance of the foreign currency market is affected by its own lagged shocks and news and its own lagged conditional variance in periods three and four. In contrast, only its own lagged shocks/news affect its volatility in periods one and two. This demonstrates the persistence of short-term volatility in their respective markets.

It is intriguing to observe the fluctuating spillover effects amongst the four markets during the aforementioned time periods. To begin with, the current state of the stock market in period one is influenced by shocks and news spillovers from the foreign exchange, gold, and oil markets. In contrast, the second and fourth periods demonstrate no spillover effects of lagged shocks or news from any market on the current volatility of the stock market. Contrarily, period 3 mainly reflects lagged shocks and news spillovers from the foreign exchange market. Noting the GARCH spillover effects from other markets to the stock market, it is observed that in period 1, it is the lagged conditional variance spillover from the foreign exchange and oil markets, while in period 3, it is the lagged conditional variance spillover from the oil market alone, demonstrating that negative conditional variance has a greater effect than a positive conditional variance. In period four, the current conditional variance of the stock market is only affected by the lagged conditional variance of the gold market. This is an intriguing case about the stock market, which demonstrates that the economic crisis has a significant impact on it, highlighting the strong association between the four markets during the economic crisis but not during political or pandemic catastrophes. The current conditional variance of the foreign exchange market is affected by lagged shocks/news from the stock market alone in period 1, by lagged shocks/news from the stock and oil markets in periods 3 and 4, and negative shocks from the stock market increase volatility more than positive news. During period 2, there were no shocks or news spillovers from other markets. In analyzing the impact of lagged conditional variance from other markets on the current conditional variance of the foreign currency market, it can be seen that in periods 1 and 4, only the gold market is responsible for the spillover. Period 2 is influenced by the stock, gold, and oil markets. In period three, the only source of spillover is the oil market.

The current conditional variance of the gold market is influenced by shocks/news from the stock market alone in period 1, the stock market and oil market in period 2, and the stock market, oil market, and foreign exchange market in period four. In phase three, however, there is no shock or news spillover from other markets to the gold market. The current conditional variance of the gold market in periods 1 and 4 is influenced by the conditional variance of the foreign exchange, stock, and oil markets that occurred in the past. In period 3, only the foreign currency market exhibits lagged conditional variance spillover, whereas, in period 2, no markets exhibit lagged conditional variance spillover. In the case of the oil market, the present conditional variance is influenced by lagged shocks/news spillover from the foreign exchange market alone in period 1, the gold market alone in periods 2 and 4, and none in period 3. In addition, the current conditional variance of the oil market is affected by the lag condition variance spillover from the stock and foreign exchange markets in period 1, the foreign exchange market alone in period 2, the stock and gold markets in period 3, and the stock, foreign exchange, and gold markets in period 4. In addition, period 3 demonstrates that lagged negative conditional variances from the stock and gold markets enhance volatility relative to lagged positive conditional variances.

CONCLUSION

The objective of the study is to analyze the transmission among the four dominant markets, which are highly susceptible to major economic changes. The study attempts to capture the volatility transmissions amongst the four markets using the BEKK-GARCH model. The study is divided into four periods confirmed by the Chow Test, i.e. the post-global crisis 2008 from 2010 to 2014, which is characterized by recovery from the global financial crisis 2008 and the foreign exchange crisis 2013, which led to increased interconnectedness amongst the markets. These findings are in line with the study by Kakinuma (2021). Similarly, the fourth period, i.e., the COVID period from 2020 to 2022, too, experienced transmissions between the markets, which witnessed an extensive spillover amidst stalled economic activities. The global oil prices showcased a negative price trend, whereas gold prices spiked during this period. The second period, i.e., the post-government change period from 2014 to 2016, showed no evidence of increased scaled volatility transmissions, which can be attributed to positive investor sentiments towards the economic and monetary policies introduced. On the contrary, the third period from 2016 to 2020, i.e. the post-BREXIT referendum, had a negative impact on the volatility transmissions. Though the scale of transmission did not increase, the negative news during this period increased the volatility spillover magnitude amongst the market. The effect of this geopolitical move negatively affected the Indian markets through foreign exchange and stock markets as India is a major exporter rather than an importer of Britain. Previous studies claimed the gold market has the ability to hedge against stock market volatility. The study shows that volatility in gold prices is affected by the volatility spillover from the stock market. This has led to weekend diversification opportunities that were otherwise facilitated by gold markets. The present study contributes three major findings to the existing literature on interlinkages among financial assets. First that the gold does not stand as a hedge and be termed as a safe heaven. Recent trends have changed the dynamics of the gold market, which was conventionally considered a safe haven. Secondly, market interconnectedness increases during the crisis period. Thirdly, the political conditions domestically and geopolitical conditions globally do not increase the scale of spillover amongst the financial assets though they do have an impact on the magnitude of spillover.

The impact of investor behavior during the economic situation on portfolio management is considerable. The study's findings have practical implications for portfolio diversification and risk management. As diverse financial assets become increasingly interconnected, the study suggests that options for diversification are shrinking. The results align with the existing studies (Lee et al., 2016; Kakinuma, 2021). The results derived from the study may not be valid for other scenarios. Further research can focus on exploring the safe heaven assets other than conventionally known assets such as currency and commodities for hedging purposes.

http://dx.doi.org/10.21511/imfi.20(2).2023.05

AUTHOR CONTRIBUTIONS

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