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Asymmetric connectedness among BSE SENSEX, INR–USD exchange rate, gold price and crude oil price: fresh evidence from nonlinear ARDL

Animesh Bhattacharjee
Faculty of Management and Commerce, ICFAI University Tripura, Agartala, India

Abstract

Purpose – This paper investigates the asymmetric connectedness among the Indian stock market, crude oil price, gold price and the USD–INR exchange rate.

Design/methodology/approach – We construct a nonlinear autoregressive distributed lag model that contains the four aforementioned variables. We further used the pairwise Granger causality test to identify the direction of causality.

Findings – The results verify an asymmetrical long-run co-movement between the Indian stock market index, exchange rate, international crude oil prices and gold prices. In the long run, the performance of the Indian stock market is mainly affected by both positive as well as negative shocks in the INR–USD exchange rate, positive shocks in gold prices and positive shocks in crude oil prices. Further, a feedback mechanism is observed between positive shocks in the INR–USD exchange rate and Indian stock market performance.

Originality/value – The research paper revisited the linkage among the variables using a novel methodology proposed by Shin *et al.* (2014).

Keywords Nonlinear connectedness, Exchange rate, Crude oil price, Gold price, NARDL

Paper type Research paper

1. Introduction

Performance on the stock market reflects current changes in the economy. It implies that the macroeconomic situation of a nation affects how that nation's stock market behaves. Changes in macroeconomic conditions become risk factors in investors' portfolio substitution, claim Ratanapakorn and Sharma (2007). Among the macroeconomic elements that can be risky include real output, money supply, interest rates, inflation, governmental policies and the inflow and outflow of foreign institutional investments. Theoretical justifications and empirical proof were offered by Bahmani-Oskooee and Saha (2015), Lean, Halim, and Wong (2005), Gokmenoglu and Fazlollahi (2015) and Wanat, Papież, and Smiech (2015) that variables like the price of crude oil, the price of gold and exchange rates can impact the stock market just like any other macroeconomic factor. Given that India is the world's top consumer of both gold and oil (Jain & Biswal, 2016), along with the fourth-largest importer of both, changes in the pricing of both commodities might have a considerable effect on the value of the rupee, the stock market and other economic activity. India uses 29% of its total energy from oil, and there appears to be no way to reduce this

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dependence in the future. Additionally, it has been seen that a rise in foreign portfolio investment flow coincides with a bull market in Indian stocks, which results in a strengthening of the local rupee. Because of this, it is crucial for investors, portfolio managers and policymakers to understand the dynamic relationships between the prices of gold, oil, the dollar, the stock market and other commodities.

There is a scarcity of research that has delved into the asymmetric relationship between exchange rates, gold prices, crude oil prices and the performance of the Indian stock market. Merely two empirical studies (Kumar, Choudhary, Singh, & Singhal, 2021; Asad, Tabash, Sheikh, Al-Muhanadi, & Ahmad, 2020) scrutinizing the impacts of positive and negative shocks on the exchange rate, gold price and crude oil price on the Indian stock market performance within a multivariate framework were uncovered in our review of the literature. Moreover, there has been no exploration into the predictive causality between the Indian stock market performance and positive and negative shocks affecting the exchange rate, gold price and crude oil price. Through an examination of the asymmetrical relationship among the INR–USD exchange rate, gold price and crude oil price, this present study adds to the existing body of literature. Additionally, this study delves into predictive causality utilizing an asymmetrical pairwise Granger causality test. We have utilized a recently developed methodology by Shin, Yu, and Greenwood-Nimmo (2014) to investigate the asymmetrical connections between the variables.

The rest of the study is arranged as follows: Section 2 deals with the theoretical as well as empirical literature; Section 3 provides the description of data and explains the methodology adopted to investigate the relationship between the variables, Section 4 contains the analysis, and Section 5 provides the implications and the conclusion.

2. Literature review

Three sections make up the theoretical and empirical literature. The literature on the symmetrical and asymmetrical links between the exchange rate and the stock market is included in Section 2.1. The literature on the symmetrical and asymmetrical links between the price of gold and the stock market is found in Section 2.2. The literature on the symmetrical and asymmetrical relationships between the price of crude oil and the stock market is found in Section 2.3.

2.1 Relationship between exchange rate and stock market performance

There are two prominent theories that explain the relationship between exchange rate and stock market performance. Wealth is the main factor influencing the foreign exchange rate, as per the portfolio balance approach. According to Bahmani-Oskooee and Saha (2015), rising stock prices improve people's wealth. The demand for money raises as public wealth rises, which rises interest rates. Rising interest rates bring in foreign investment, which strengthens the domestic currency. According to the notion, fluctuations in stock prices are responsible for changes in exchange rates. On the other hand, the traditional strategy holds that a weak domestic currency makes domestic businesses more competitive on the world market. Under the floating exchange rate regime, Aggarwal (2003) investigated the relationship between exchange rate and US stock prices and found that there was a positive correlation between the two. Granger, Huangb, and Yang (2000) found a significant link between stock prices and currency rates for Thailand and Japan. Following the 9/11 terrorist attack, Lean *et al.* (2005) discovered that the stock markets in Japan, the Philippines, Korea, Hong Kong, Malaysia and Indonesia had weak long-run relationships with foreign exchange rates using a cointegration test based on ordinary least squares (OLS) and the Granger causality test. In 2005, Erdem *et al.* employed the exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model to find evidence of negative volatility spillover from exchange rate to stock market indices. Alagidede, Panagiotidis, and Zhang (2011) used three different iterations of the Granger causality test and discovered unidirectional correlation between stock prices and currency rates, while the study showed bidirectional causality for Switzerland. In addition, prices from the stock market spilled over to the foreign exchange market in Thailand, Indonesia, Korea, Malaysia and Taiwan, according to Lee, Doong, and Chou (2011). According to Liu and Tu (2011), excessive foreign capital purchases and sales have an impact on both the foreign exchange rate and the index of the Taiwanese stock market. Helmy (2024) examined the long-run and short-run relationship between stock prices in the Eygptian stock market on the one hand and interest rate, inflation and exchange rate on the other. The author concluded that the domestic exchange rate had an asymmetrical impact on the Eygptian stock market in the long run as well as in the short run.

2.2 Relationship between gold price and stock market performance

Gold has historically served as an inflation signal, a hedge against inflation, a crucial component in portfolio allocation and a role in inflation since it functions as a hedge to diversify the market's heightened risk during crises. Central banks and other international financial institutions hold significant amounts of gold on hand for economic security and diversification. One of the ten nations with gold reserves is India. In India, gold is seen as a status symbol in addition to acting as a hedge. Additionally, large amounts of gold are bought during festival and wedding seasons since it is thought that gold bestows happiness and luck onto newlyweds. In India, there are several ways to invest in gold. Wanat *et al.* (2015) investigated the causation in distribution between European stock markets and commodity prices using a separate test based on the empirical copula (gold and oil prices). Researchers discovered an erratic and asymmetric relationship over time between European stock markets and gold prices. They came to the conclusion that European stock market investors saw gold as a "safe haven." Linear ARDL was used by Gokmenoglu and Fazlollahi (2015) to examine the relationships between gold, oil and the US stock market. According to the research, gold has a significant influence on the US stock market, and investors respond to variations in gold prices over time. The authors arrived at the conclusion that the mood of investors was not much impacted by short-term volatility. Mishra, Das, and Mishra (2010) used a linear approach in the Indian context to investigate the relationship between gold price volatility and Indian stock market returns between January 1991 and December 2009. The researchers' findings confirmed that there is a bi-directional causal relationship between the variables and that gold prices and the Indian stock market are cointegrated. But Srinivasan (2014) did not discover any long-term correlation between the prices of gold and the Indian stock market. Bhuvaneshwari and Ramya's (2017) findings, which were based on sample data from January 2011 to December 2015, corroborate those of Srinivasan (2014). They came to the conclusion that it is impossible to forecast the behavior of the Indian stock market using historical gold price data. In a nonlinear setting, Asad *et al.* (2020) found that the stock market in Pakistan was not sensitive to positive shocks in the gold price before the 2008 financial crisis; however, the stock market showed negative linkage with the positive changes in the gold price after the 2008 crisis. Using a large dataset from 2000 to 2022, Cui (2023) found that gold prices were positively correlated with Chinese stock market indexes, indicating a relationship where gold and stock prices move in the same direction in China. Tran and Nguyen (2022) employed panel VAR and datasets from 55 Asian countries and 32 European countries and found that in Asian countries there was a bidirectional causality between the stock market and gold price, while in Europe, they had a causal relationship at a 1% significant level.

2.3 Relationship between crude oil price and stock market performance

de Jesus, Bezerra, and da Nóbrega Besarria (2020) explained that changes in anticipated future cash flows or discount rates may be responsible for the relationship between stock prices and crude oil prices. Changes in crude oil prices can have an impact on production costs because oil plays a significant role in the production process for the majority of firms. The earnings and dividend payments of the companies will be affected by variations in the cost of production, which will have an impact on the stock prices. Furthermore, higher oil prices could cause the predicted inflation to be overestimated, which would raise nominal interest rates. Since discount rates and stock prices are inversely correlated, rises in interest rates bring down stock prices.

In a linear multivariate framework, Gokmenoglu and Fazlollahi (2015) found that international oil prices affected the S&P 500 index negatively in the long run, while in the short run, lagged crude oil prices affected the current S&P 500 index. In four nations in south Asia, Alamgir and Amin (2021) looked into the nonlinear relationship between oil prices and stock market performance of South Asian countries. They discovered that the relationship between the price of oil and stock market performance was cointegrated across all countries, with both positive and negative effects on stock market performance. The study also stated that rising oil prices boost stock prices. Kumar (2019) found nonlinear causality running from oil price to stock prices in India. Pruchnicka-Grabias (2022) employed an unrestricted VAR model and found that in the short run, crude oil prices significantly influenced the US stock market, but the reverse relationship was not observed. The study concluded that stable oil prices are crucial for stock market stability.

3. Data and methodology

3.1 Data sample

The study provides an insight at how the performance of the Indian stock market is affected asymmetrically by the exchange rate, the price of crude oil and the price of gold. The study is empirical and draws on data from observations made between 2015:01 and 2021:12. To prevent the data set from having too many structural breaks, we chose a brief time period. The regression model's parameters may become unstable in the presence of structural breaks. The study's variables include the stock market index (represented by the BSE SENSEX), exchange rate (represented by the INR–USD exchange rate), exchange rate, oil price and oil price. The data used to calculate the stock market index was obtained from www.bseindia.com. The information on the exchange rate and gold price is gathered from www.rbi.org.in and www.gold.org, respectively, while the data on crude oil prices is sourced from www.data.nasdaq.com.

The functional model of the study is provided below:

$$Sensex = f(Exchange\ rate, Gold\ price, Crude\ oil\ Price)$$

3.2 Methodology

Testing for unit root is essential because the variables are time series in nature. As a result, the augmented Dickey–Fuller (ADF) test and the Phillips–Perron (PP) test were both used in the current study. For analyzing the long- and short-term relationships between the Indian stock market, the INR/USD exchange rate, the price of crude oil, and the price of gold, it makes use of the nonlinear autoregressive distributed lag model (NARDL). NARDL approach is an extension of the linear autoregressive distributed lag model (ARDL).

There are two steps in the ARDL approach. In the initial stage, an F-test is used to assess the long-run linkage. In the event where the estimated F-statistic is smaller than the lower bound value, no cointegration between the variables is inferred. If the estimated F-statistic is between the lower and upper bound values, it is considered that the cointegration between the included variables is inconclusive. Cointegration is stated to exist if the F-statistic value exceeds the upper bound value. It should be emphasized that the ARDL modeling variables should only be integrated to order 1 or fewer.

The general form of the error correction model in the linear ARDL model is presented below:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 X_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{i} \theta_j \Delta X_{t-j} + \varepsilon_t \quad (1)$$

where, X_t is the logarithm of independent variable series and Y_t is the logarithm of dependent variable series.

In the second stage, the ordinary least squares approach is used to calculate the short-run parameters. The short-run model also includes the error correction term, which shows how quickly the long-run equilibrium is recovered following a short-run shock.

The NARDL model is a versatile econometric framework that has gained significant attention in the field of time series analysis. This approach extends the traditional ARDL model by allowing for nonlinear relationships between the variables of interest, making it particularly suitable for capturing complex dynamic interactions. The NARDL model was introduced as a generalization of the standard ARDL model, which has been widely used to study both short-run and long-run relationships between variables. Unlike the ARDL model, which assumes a linear relationship, the NARDL model relaxes this assumption and allows for asymmetric adjustments, where positive and negative shocks may have different impacts on the dependent variable. This flexibility is particularly useful in situations where the underlying economic relationships exhibit nonlinear characteristics, such as in the case of macroeconomic variables or financial time series. The NARDL model has been successfully applied in a variety of research domains, including macroeconomics, finance and energy economics, to investigate dynamic relationships and test for the presence of asymmetric effects.

For the NARDL model (proposed by Shin *et al.*, 2014), the exchange rate series gold price series is decomposed into positive shocks and negative shocks. The cointegrating regression equation of the NARDL model can be represented as:

$$Y_t = \beta^+ X_t^+ + \beta^- X_t^- + \varepsilon_t$$

where, $\beta^+ X_t^+ and\, \beta^- X_t^-$ are long-run asymmetrical parameters. X_t is a Kx1 vector of Y_t and can be decomposed as:

$$X_t = X_0 + X_t^+ + X_t^- \quad (2)$$

Thus, fluctuation in gold prices can be decomposed in the following way:

$$Gold_t^+ = \sum_{i=1}^{t} \Delta goldprice_t^+ = \sum_{i=1}^{t} \max(\Delta x_i, 0)$$

$$Gold_t^- = \sum_{i=1}^{t} \Delta goldprice_t^- = \sum_{i=1}^{t} \min(\Delta GP_i, 0)$$

Fluctuations in INR–USD exchange rate can be decomposed in the following way:

$$Exchangerate_t^+ = \sum_{i=1}^{t} \Delta INR\text{–}USD\,Exchange\,rate_t^+ = \sum_{i=1}^{t} \max(\Delta x_i, 0)$$

$$Exchangerate_t^- = \sum_{i=1}^{t} \Delta INR\text{–}USD\,Exchange\,rate_t^- = \sum_{i=1}^{t} \min(\Delta GP_i, 0)$$

And, fluctuations in crude oil prices can be decomposed in the following way:

$$Crude_t^+ = \sum_{i=1}^{t} \Delta Crude\,oil\,prices_t^+ = \sum_{i=1}^{t} \max(\Delta x_i, 0)$$

$$Crude_t^- = \sum_{i=1}^{t} \Delta Crude\,oil\,prices_t^- = \sum_{i=1}^{t} \min(\Delta GP_i, 0)$$

Combining Equation (1) and Equation (2) the error correction model in the nonlinear ARDL model can be written in the following way:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2^+ X_{t-1}^+ + \alpha_3^- X_{t-1}^- + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{i} \left(\theta_j^+ \Delta X_{t-j}^+ + \theta_j^- \Delta X_{t-j}^- \right) + \varepsilon_t$$

Further, in order to capture the adjustment asymmetry, we have computed the dynamic multipliers.

The study also employs an asymmetrical pairwise Granger causality test to determine the short-term prediction ability of the variables.

4. Results

The current study uses two distinct unit root tests to determine whether LnSensex, LnExchangerate, LnGold and LnCrude are stationary. Both the PP test and the ADF test show that the variables have a unit root at level (see Table 1). The variables do, however, become stationary in their first-difference form. As a result, the variables are said to be integrated of order 1. After performing the unit root test we proceed towards applying the NARDL approach.

We run the *F*-bounds test to determine whether these macroeconomic variables move together with the Indian stock market index. Table 2 displays the outcome of the F-bounds test. It can be inferred that cointegration exists if the estimated *F*-statistic is greater than the upper bound critical values. It is assumed that there is no cointegration if the computed *F*-statistic is below the lower bound critical values; however, if it falls between the lower

Variables	ADF Level	ADF 1st difference	PP Level	PP 1st difference	Remark
LnSensex	0.066[n]	−9.565[a]	0.183[n]	−9.565[a]	I(1)
LnExchangerate	−1.5892[n]	−9.573[a]	−1.493[n]	−9.662[a]	I(1)
LnGold	−0.735[n]	−6.902[a]	−0.437[n]	−6.716[a]	I(1)
LnCrude	−2.554[n]	−7.454[a]	−2.676[n]	−8.115[a]	I(1)

Note(s): [a]means the null hypothesis is significant at the 1% level, whereas [n]means it is not
Source(s): Author's own

Table 1. Unit root test

bound critical value and upper bound critical value, it can be assumed that the cointegration test is ambiguous. From observation of the values in Table 2, it is evident that at the 5% level of significance, the computed F-statistic (4.196) is larger than the upper bound critical value of 3.28 and the lower bound critical value of 2.27. Thus, the null hypothesis of no cointegration is rejected. The results indicate an asymmetrical long-run co-movement between the Indian stock market index, exchange rate, international crude oil prices and gold prices.

The long-run parameters are summarized in Table 3. In the long run, both positive and negative shocks in the exchange rate negatively affect the Indian stock market index. Accordingly, a unit rise in the USD–INR exchange rate depresses the Indian stock market index by 0.725%. Further, a unit fall in the USD–INR exchange rate depresses the Indian stock market index by 2.792%. The study further documents a negative relationship between positive shocks in the gold price and the Indian stock market index. We observed that a unit rise in the gold price is expected to be followed by a fall in the Indian stock market index by 0.436%. In the case of crude oil prices, positive changes in oil prices in the world market exert a positive impact on stock prices in India. It can be observed that a unit rise in crude oil price is expected to be followed by an improvement in the Indian stock market index by 0.340%.

The short-run parameters and the convergence coefficient are reported in Table 4. It can be observed that both current period positive shocks in the INR–USD exchange rate and current period negative shocks in the INR–USD exchange rate adversely influence the Indian stock market performance in the short run. We also document that the Indian stock market's performance responds to the negative shocks in oil prices rather than the positive shocks in the short run. It can be seen that negative shocks in crude oil price in the current period positively influence the stock market index, while one-month lag negative shocks in crude oil price adversely affect the Indian stock market index in the short run. The convergence coefficient or error correction term, is negative and statistically significant, suggesting that

Table 2. Cointegration test

Cointegration test			
Significance	10%	5%	1%
I(0)	1.99	2.27	2.88
I (1)	2.94	3.28	3.99

Note(s): Computed F-statistic = 4.196
Source(s): Author's own

Table 3. Asymmetric long-run parameters

Regressors	Coefficient	t-statistic
$\text{LnExchangerate}^{+}$	−0.725	-2.376^{**} (0.305)
$\text{LnExchangerate}^{-}$	−2.792	-3.305^{*} (0.844)
LnGold^{+}	−0.436	-1.748^{***} (0.249)
LnGold^{-}	0.402	1.371 (0.293)
LnCrude^{+}	0.340	3.388^{*} (0.100)
LnCrude^{-}	−0.127	−1.095 (0.116)
c	8.934	26.723^{*} (0.334)

Note(s): The standard errors presented in parentheses are estimated using the Newey–West method and are robust to heteroscedasticity
Source(s): Author's own

Regressors	Coefficient	*t*-statistics
$\Delta \ln Sensex_{t-1}$	0.017	0.188 (0.093)
$\Delta \ln Exchangerate_t^+$	−0.815	−1.788*** (0.455)
$\Delta \ln Exchangerate_t^-$	−1.983	−5.188* (0.382)
$\Delta \ln Exchangerate_{t-1}^-$	0.559	1.415 (0.395)
$\Delta \ln Gold_t^+$	−0.410	−1.587 (0.258)
$\Delta \ln Gold_t^-$	−0.077	−0.221 (0.351)
$\Delta \ln Crude_t^+$	−0.0177	−0.355 (0.050)
$\Delta \ln Crude_{t-1}^+$	−0.015	−0.493 (0.032)
$\Delta \ln Crude_t^-$	0.257	4.121* (0.062)
$\Delta \ln Crude_{t-1}^-$	−0.107	−2.187** (0.049)
c	0.003	0.435 (0.008)
Convergence coefficient	−0.407	−5.728* (0.071)

Source(s): Author's own

Table 4.
Asymmetric short-run parameters

the Indian stock market index returns to long-run equilibrium after short-run shocks, and the speed of adjustment is 40.7% per month.

The results of various diagnostic tests performed on the residuals of the nonlinear ARDL model are shown in Table 5. To determine whether the residuals are normal, we used the Jarque–Bera test. The outcome demonstrates that the Jarque–Bera test statistic is insignificant at the 5% level, suggesting that the model's residuals are normally distributed. To ascertain whether there is serial correlation in the residuals, the Breusch–Godfrey test and Lagrange multiplier (LM) test are applied. We discover that the test statistic is non-significant at the 5% level, indicating that there is no serial correlation in the residuals. To determine whether the residuals are heteroskedastic, we used the autoregressive conditional heteroskedasticity (ARCH) test. The ARCH test's test statistic is not significant at 5%, which indicates that the residuals are homoskedastic. The CUSUM plot and the CUSUM of Squares plot are stable, suggesting that the computed parameters are reliable and can be used for policy-making.

The pairwise asymmetric granger causality results are portrayed in Table 6. The table reports that bi-directional causality runs from positive shocks in exchange rate and Indian stock market index. It can also be observed that weak unidirectional causality flows from negative change in exchange rate to Indian stock market performance. We can also observe strong unidirectional causality running from positive shocks in gold price to stock market index and negative shocks in gold price to stock market index. The results give the impression that changes in the INR–USD exchange rate, variation in the gold price and crude oil price have the ability to predict the stock market performance in the short run. We have observed a feedback mechanism between positive shocks in the exchange rate and Indian stock market performance.

	Test statistic	*p*-value
Normality test	0.435	0.804
serial correlation test	0.745	0.4781
ARCH test	2.863	0.0945

Note(s): CUSUM plot are found to be *Stable*
CUSUM of Squares plot are found to be *Stable*
Source(s): Author's own

Table 5.
Residual diagnostics

Table 6.
Asymmetrical Granger causality test

	F-statistic	p-value
$\text{LnExchangerate}^{+} \overset{DNGC}{\longrightarrow} \text{LnSensex}$	2.603***	0.0755
$\text{LnSensex} \overset{DNGC}{\longrightarrow} \text{LnExchangerate}^{+}$	3.393**	0.0347
$\text{LnExchangerate}^{-} \overset{DNGC}{\longrightarrow} \text{LnSensex}$	2.849***	0.0592
$\text{LnSensex} \overset{DNGC}{\longrightarrow} \text{LnExchangerate}^{-}$	1.881	0.1539
$\text{LnGold}^{+} \overset{DNGC}{\longrightarrow} \text{LnSensex}$	4.833*	0.0085
$\text{LnSensex} \overset{DNGC}{\longrightarrow} \text{LnGold}^{+}$	1.142	0.320
$\text{LnGold}^{-} \overset{DNGC}{\longrightarrow} \text{LnSensex}$	3.334**	0.0368
$\text{LnSensex} \overset{DNGC}{\longrightarrow} \text{LnGold}^{-}$	1.437	0.2390
$\text{LnCrude}^{+} \overset{DNGC}{\longrightarrow} \text{LnSensex}$	3.877**	0.0216
$\text{LnSensex} \overset{DNGC}{\longrightarrow} \text{LnCrude}^{+}$	1.544	0.2149
$\text{LnCrude}^{-} \overset{DNGC}{\longrightarrow} \text{LnSensex}$	4.481*	0.0120
$\text{LnSensex} \overset{DNGC}{\longrightarrow} \text{LnCrude}^{-}$	1.893	0.1521

Note(s): $\overset{DNGC}{\longrightarrow}$ represents does not Granger cause
Source(s): Author's own

5. Implications and conclusion

The current study explores the asymmetric relationship between the INR–USD exchange rate, gold price, crude oil price and performance of the Indian stock market. The study employed nonlinear ARDL to analyze the long-run and short-run parameters and used the latest approach proposed by Shin *et al.* (2014) to decompose the exchange rate series, gold price series and crude oil price series into positive shocks and negative shocks. The study found cointegration among the variables, indicating a long-run equilibrium relationship between the performance of the Indian stock market and positive and negative shocks to the domestic currency, the price of gold and the price of crude oil. This finding corroborates the evidence provided by Sheikh, Asad, Ahmed, and Mukhtar (2020) and Asad *et al.* (2020), but contradicts the findings of Kumar *et al.* (2021).

We provide plausible explanations for the long-run results observed above. The rise in gold price and the Indian stock market have a negative association, according to our findings. The negative link backs with the hypothesis that gold can be used as a hedge against a falling stock market. Investors avoid risky stock investments in times of uncertainty, geopolitical threats and high inflation by moving to safer havens. This result is in support of the findings made by Asad *et al.* (2020) in the post-2008 crisis regime.

The study's intriguing finding that there is a direct relationship between positive shocks in crude oil prices and the Indian stock market in the long run. This discovery supports the findings provided by Alamgir and Amin (2021). In the world market, a shared underlying component, aggregate demand, affects both stock prices and crude oil prices. As aggregate demand declines, so does demand for oil, lowering crude oil prices. On the contrary, rising aggregate demand increases the demand for oil, thus, pushing the crude oil prices upward. Falling aggregate demand signals slowing down of economic activities in oil-importing economies. Softening of aggregate demand hurts corporate profits, thereby, lowering the demand for stocks. The decrease in the demand causes the stock prices to go down. On the other hand, increasing aggregate demand pushes the price of crude oil to rise. It also signals increase in economic activities in oil-importing nations. Increasing aggregate demand boost corporate profits and investment in stock becomes attractive. The study found that both positive and negative changes in the INR–USD exchange rate negatively affect the Indian stock market in the long run as well as short run. It is observed that negative changes in the exchange rate have more adverse influence on the stock market as compared to positive changes in the exchange rate.

The findings have several real-world implications. The long-term inverse relationship between positive gold price shocks and the index of the Indian stock market shows that investors can use gold as a long-term hedge against the declining Indian stock market. The positive linkage between positive shocks in crude oil prices and Indian stock market performance shows that the Indian stock market does not follow the efficient market hypothesis and is in line with the claim of Alamgir and Amin (2021).

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Corresponding author
Animesh Bhattacharjee can be contacted at: bhatt.ani725@gmail.com