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METHODS

Interdependency between Indian and US market indices: A granger causality approach

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The Granger causality model is used in the current study to analyze the short-run cause–effect relationship between two stock market indices between 2001 and 2021 using time series data of the daily closing prices of the BSE Sensex and S and P 500 indices listed in the Indian and US stock markets, respectively. The Granger causality model and the augmented Dickey–Fuller test for data stationarity were used in the study to examine the short-term causal link between two market indices during the time period. The outcomes demonstrated the connection between the Indian and US stock markets. The findings imply that both markets have a dynamic, bidirectional relationship. This study provides the investor's essential inputs for investment decision-making and portfolio diversification. In the current era of globalization, the study is crucial because investors and fund managers now place a high priority on stock market integration. Through fund diversification across equity markets, this study subsequently makes it easier to reduce portfolio risk by providing useful insights on diversification strategies across the stock markets.

Keywords: BSE sensex, S and P 500, granger causality test, augmented dickey–fuller test

Introduction

Stock observe the growth of autocorrelations in stock return patterns as a result of the capital markets' openness to international investors (1). These autocorrelations in stock returns demonstrate a type of dynamic association of time series data and explain how investors make investment decisions. According to the phenomenon of autocorrelation, one stock market has a significant influence on another (2).

These influences of one market on another are known as "conditional volatility" due to the autoregressive conditional hetero-skedasticity (ARCH) effect in the data (periods of high volatility are followed by periods of high volatility, and periods of low volatility are followed by periods of low volatility in stock return data) and the presence of the ARCH effect in the volatility cluster of stock return data. More specifically, it contends that significant volatility in stock returns frequently follows more minor changes and vice versa. It highlights the fact that past trends of investment in foreign and domestic markets have had an impact on current investment decisions.

These changes in the form of clusters in stock return data represent conditional volatility. Further to this, the conditional volatility concept suggests that the present volatility of stock return is determined by the past volatility of stock return (also known as an independent variable to measure the volatility of stock return for the present time period). With the aid of the Granger causality model, the current study seeks to identify the dynamic interaction between the two markets (i.e., the stock markets of the United States and India).

The Indian stock market has many US investors, which implies that the US market volatility has a great impact on the Indian stock market. Several empirical analyses also suggest a dynamic association between the volatility of these two stock markets (the United States and India).

Furthermore, the United States was one of India's most important commercial partners.

Because of the United States and India's positive economic and commercial relations, India's exports to the United States represented 17.4% of total exports during the 1995–1996 period and climbed to 22.8 percentage points during the 1999–2000 period. For the same time frame, imports made up 10.5 and 7.2% of all imports, respectively. Due to India's concentration on other emerging nations following the 2002–2003 era, the percentage of total exports decreased.

The current study's objective is to test the idea that capital transfers between markets affect trade volume, creating a highly integrated stock market. The Granger causality test was used in the study to examine the causal connection between the two time series (the United States and India) and determine whether they are complementary for forecasting. Many academics often employ the ARCH approach to determine the conditional volatility of stock markets.

The residuals in ARCH modeling are calculated using the mean equation, transferred to the variance equation to further assess the residual normality distribution, and finally the best fit model is determined using the Akaike information criterion (AIC) and/or SIC criterion. The residuals are also known as error terms, and in ARCH modeling conditional variance becomes a function of historical variance. Furthermore, this method allows historical variance to change over time (3).

According to Engle (3), unanticipated variations in stock returns over time have a substantial impact on the stock market's volatility. Bollerslev (4) expanded the ARCH process by enabling the conditional variance to be a function of both the lagged value of the conditional variance and the past error term. Its fundamental tenet is that investors' present decision-making is significantly influenced by the residuals (past error term), which also influences their historical volatility. Since Engle initially described them in 1982 and Bollerslev et al. (5) subsequently extended them, these models have been frequently used to explain and model the time series data of stock markets.

The paper consists of five sections; (a) the section titled, "Introduction" introduces the concept with explanation of aim of the study; (b) the section titled, "Literature Review" elaborates the extant literature related to the study; (c) the section titled, "Data and Research Methodology" follows the "Literature Review" section; (d) the section titled, "Empirical Findings" follows the "Data and Research Methodology" section; and (e) the section titled, "Conclusions and Implications of the Study" concludes the paper.

Literature review

The current study credits Grubel (6) investigation into the advantages of world diversity as the source of its inspiration. Due to the continuing liberalization of emerging markets, investors are diversifying their portfolios to reduce risk. Whenever there is a negative correlation between stock returns in different markets, international diversification should help the investor reduce risk.

The information from one market can be used to forecast the movement of another market if the stock returns of different countries are positively correlated. Scholars have tried to quantify the connectedness between the stock markets. This relationship is termed "dynamic interdependence," and it consists of four measures of market dynamic linkage, i.e., "cause and effect" (causality), "spillover effect" (both market volatility and return) "co-integration," and "connectedness" (7).

Existing literature investigates and explores all four measures to identify market dynamic linkages in various sample periods and market conditions using various techniques and models. Co-integration, correlations, the univariate Granger causality model, the GARCH (p, q) model, and the ARMA-GARCH model were previously used to estimate dynamic linkages between stock market return and volatility spillover. For example, Rao and Naik (8) found through cross-spectral analysis that there was a weak relationship between the Indian market and other global markets.

A two-stage GARCH model was used in several types of research to examine the dynamic interaction between stock markets utilizing daytime and overnight returns (9). In order to estimate the overnight returns of the other market, the authors first used the unanticipated shocks from one market's daytime returns as a stand-in for volatility surprises. Studies by Longin and Solnik (10) show a strong link between stock market gains and periods of high volatility. However, these studies found that this connection changes over time.

Moreover, based on the identified connectedness among the financial markets globally, recent researchers conducted a study on the dynamic linkages between macroeconomic variables and stock markets across the globe. The studies use advanced econometric techniques such as VAR-GARCH-BEKK, GVAR, GARCH-BEKK, BEKK-MGARCH, and others to identify dynamic linkages such as spillover effect, contagion, shock transmission, and so on (7, 11, 12). But there is no superior model due to varied market conditions (13).

For example, Kumar (14) investigated trade interdependency among four South Asian countries. The author applied the Granger causality model to test short-run causality among the markets. The result highlights a short-run, bidirectional causal relationship among stock markets in India, Pakistan, and Sri Lanka.

Similarly, a study was conducted to determine the degree of interconnectedness between the US equity market and seven European markets. The study employs a nonlinear causality test to assess the dynamic relationship between market returns and volatility in both crisis and boom markets. The result highlights the existence of market connectedness across countries, which sheds light on portfolio diversification strategies for investors (7).

A few studies are also being conducted on identifying the linkages between the crypto-currency market and the stock market (11, 12, 15). The studies suggested a link between stock market returns and cryptocurrency. The study also provides evidence of volatility spillover (unidirectional and/or bidirectional) between stock markets and the crypto-currency market. However, these studies found that this connection changes over time.

Furthermore, extant research that used the Granger causality model suggests that the US stock market significantly influences the integration of other stock markets (cf. (16)). According to several studies that looked at group stock markets, there is a significant interconnectedness between the stock markets [cf. (11, 12, 17, 18)]. The results of Forbes and Rigobon (19) study, which found both long- and short-term connectedness among the stock markets, support the market's interconnectedness. In the same line of thought, Bracker and Koch (20) discovered compelling evidence that monetary factors impact global interdependencies among stock markets. Moreover, Masih and Masih (21) back up the widely held belief that there is a significant short-run and long-run association between emerging Asian markets and the well-established OECD markets.

As a result, a few studies concluded that the Indian and US stock markets were not interdependent. For example, Arshanapalli and Kulkarni (22) investigated the dynamic relationship of stock markets between the United States and India using the Johansen co-integration test and found no evidence of interdependency between the United States and Indian stock markets. Despite the existence of the NAFTA pact, Ewing et al. (23) discovered that there is no market integration among the North American countries.

According to some empirical studies, there are dynamic relationships between financial indicators and stock markets (16, 20). Furthermore, the US stock market consistently outperforms other developed economies in both the short and long run. The integration of the Australian stock market with the US and Japanese markets before and during the Asian financial crisis was also studied by Shamsuddin and Kim (24).

The study discovered evidence of long-run correlation among three markets prior to the Asian crisis, but correlation among stock markets weakens after the crisis. The study also demonstrates lesser interdependency between the stock markets of the United States and Australia than the Japanese and Austrian stock markets, which are nonetheless somewhat interdependent. The author used the VAR-BEKK-GARCH method to demonstrate the interdependency between major East Asian markets and the bitcoin markets proposed by Zeng and Ahmed (15).

The outcome suggests that the Japanese and Hong Kong stock markets are moderately dependent on each other. Moreover, the stock markets have significant spillover risks to other markets. Wong et al. (25) examined the market integration of India with the United States, the United Kingdom, and Japan. The co-integration model and the Granger causality model were used to calculate short- and long-run correlation.

The authors found a long-run correlation between all three markets (the United States, the United Kingdom, and Japan) and the Indian market, and that it has evolved to reflect their traits. However, in the short run, the UK stock exchange influences the Indian stock exchange and vice versa; the Indian stock exchange has no influence on the US or Japanese stock exchanges and vice versa. Yochanan (26) estimated dynamic linkages among the BRIC countries using vector autoregression (VAR) models and found strong linkages among the countries.

The study concludes that all four member markets become more significant as globalization progresses more quickly. Additionally, using the Impulse Response model, the impact of market volatility in the United States, Japan, and India on the Bangladesh stock market was examined. The study discovered that the Bangladesh stock market was significantly impacted by US volatility. However, the volatility of the Japanese and Indian stock markets has little effect on the Bangladesh stock market.

Based on the extant literature, it can be concluded that most of the researchers indicate a high level of market integration among countries, which is increasing. Even though few studies contest this occurrence and find no evidence of a dynamic link between the markets (22, 23, 27).

Data and research methodology

The current study estimates how closely related the US and Indian stock markets are to one another by calculating their conditional volatilities. The daily prices of the NYSE-listed S and P 500 index and the Bombay Stock Exchange's (BSE) Sensex index are included in the sample data. Data were collected between January 2001 and December 2021.

The majority of the 500 large-cap stocks that make up the S and P 500 index are American. It is contained in the value-weighted components of the important S and P 1500 and S and P Global 1200 stock market indexes. The NYSE and NASDAQ, the two biggest US stock exchanges, are where all the index's component equities are traded.

It includes roughly 75% of the market and 75% of the market capitalization for US stocks. Another value-weighted index made up of 30 large-cap companies with active trading markets is the BSE Sensex.

The study contains a thorough analysis of the enhanced Dickey–Fuller test for determining data stationarity using E-Views v.20 and the Jarque–Bera test for determining conditional volatility using the Granger causality model. Initially, natural logarithmic differences are used in the estimation of stock market returns. The index's price in time period t should be represented by P_t, and its price in time period $t-1$ should be represented by P_{t-1}.

As a result, the rate of return R_{it} investors will experience over the course of time will be

$$R_t = [Log_e(P_t) - Log_e(P_{t-1})] * 100 \quad (1)$$

Empirical findings

Preliminary results

Table 1 shows the summary statistics for the return price for both time series of data, i.e., the US stock market (S and P 500) and the Indian stock market (BSE Sensex). In addition, the mean value determines the average return prices of both indices. Table 1 further indicates the positive average return prices of both the S and P 500 and the BSE Sensex, indicating an increase over the period. The skewness values suggest that both indices are positively skewed.

The positive skewness suggests that most data values shift toward the higher side. As a result, both indices have a better likelihood of producing profitable returns. The S and P 500 return has a larger tail than the conventional normal distribution, according to high values of kurtosis, whereas the BSE Sensex return has a low value of kurtosis.

To ascertain whether the data are distributed normally, the Jarque–Bera test is also used. The test's null hypothesis was that the data had a normally distributed distribution. The analysis demonstrates that the data are not normally distributed because the p-value is less than 0.05, which disproves the null hypothesis. This demonstrates that the US and Indian stock markets' returns are not allocated in a consistent manner.

Unit root test

There is a need to analyze whether the data is stationary or not to conduct econometric modeling. It is the basic assumption for conducting econometric modeling on time series data. Table 2 shows the group unit root test at the first level.

The BSE Sensex and S and P 500 indices' returning prices were evaluated for data stationarity using the augmented Dickey–Fuller test. According to Table 2, both series have a unit root at the level. Accept the null hypothesis, which states that there is a unit root in the series, because the p-value is greater than 5%. Further, it indicates unit root test results at level one or lag one in the third row of Table 2.

The test indicates a p-value of less than 5%, hence rejecting the null hypothesis. Thus, it indicates the stationarity of data in both time series, which is desirable for econometric models. Figures 1, 2 illustrate the diagrammatic representation of data stationarity.

The absence of a unit root and the presence of stationary points suggest that the data follows a proper trend. It will facilitate future forecasting of the spillover and contagion effects through volatility measures.

Granger causality test

A statistical technique called the Ganger causality test is used to establish the short-term causal link between two time series. If a time series can predict another time series, it can be determined statistically using this hypothesis test. If the probability value falls below the level of significance (5% in this case), the null hypothesis of Granger causation is rejected.

The Granger causality test is based on VAR and a reasonable number of lags. The reasonable number of lags determines the maximum time period for which one time series can be forecast for another time series. Furthermore, the number of lags was selected based on the AIC criterion.

When four lags are applied in Table 3, the first null hypothesis that the BSE Sensex does not involve the Granger causality of the S and P 500 is rejected at a 5% level of significance (refer to Equation 2). Thus, it suggests unidirectional causality running from the BSE Sensex to the S and P 500. At the 5% level of significance, the second null hypothesis, that S and P 500 does not involve the Granger causality of BSE Sensex, was also rejected (refer to Equation 3).

TABLE 1 | Descriptive statistics of the Indian and US stock markets.

	BSE Sensex	S and P 500
Mean	20270.47	1756.313
Median	18046.35	1396.160
Maximum	61765.59	4536.950
Minimum	2600.120	676.5300
Std. Dev.	13322.46	824.2623
Skewness	0.731957	1.258356
Kurtosis	3.091253	3.981032
Jarque–Bera	468.2814	1588.152
Probability	0.000000*	0.000000*

*p-value at 5% level of significance. (*Source:* Authors' own compilation.) (Data generated through E-Views v.20.).

TABLE 2 | Unit root test (Augmented Dickey–Fuller (ADF) test) for BSE sensex and S and P 500.

Augmented dickey–fuller test statistic	BSE sensex	S and P 500
Constant	1.380589 (0.9990)*	2.622967 (1.0000)*
Constant at level one	−26.65607 (0.0000)*	−23.14838 (0.0000)*

*p-value at 5% level of significance. (*Source:* Authors' own compilation.) (Data generated through E-Views v.20.).

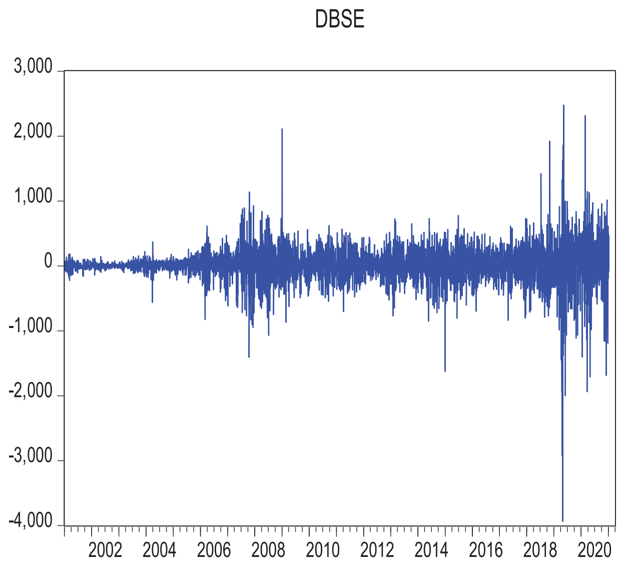

FIGURE 1 | Return clustering of BSE Sensex at first difference.

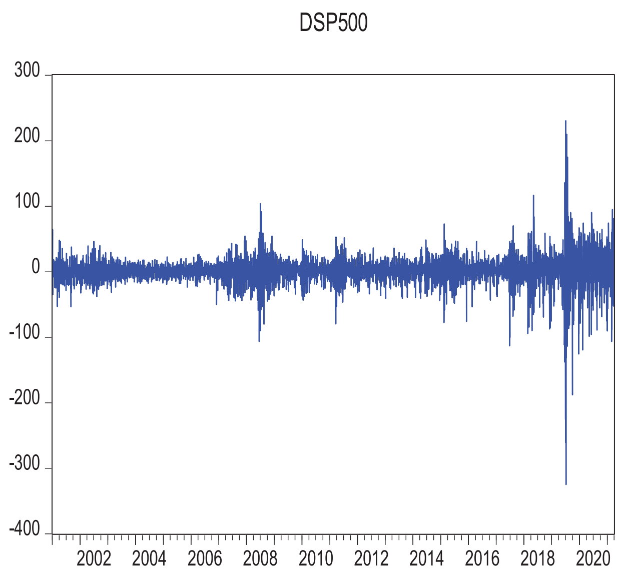

FIGURE 2 | Return clustering of S and P 500 at first difference.(*Source:* E-views V.20.).

TABLE 3 | Granger causality test result of S and P 500 and BSE sensex

Null Hypothesis	*F*-Statistics	*p*-values
BSE Sensex does not involve the granger causality of S and P 500	4.98237	0.0005*
S and P 500 does not involve the granger causality of BSE sensex	4.07188	0.0027*

*p-value at 5% level of significance. (*Source:* Authors' own compilation.) (Data generated through E-Views v.20.).

Thence, it suggests unidirectional causality running from the S and P 500 to the BSE Sensex. Moreover, it is suggested that the BSE Sensex be used to predict future values of the S and P 500 stationary time series and vice versa. Therefore, it can be said that BSE Sensex volatility causes S and P 500 volatility, and S and P 500 volatility causes BSE Sensex volatility:

$$\sigma 2_{t(BSESensex)} = \lambda 0 + \lambda 1 \sigma 2_{t-1(BSESensex)} + \lambda 2 \sigma 2_{t-1(S\&P500)} \quad (2)$$

$$\sigma 2_{t(S\&P500)} = \lambda 0 + \lambda 1 \sigma 2_{t-1(S\&P500)} + \lambda 2 \sigma 2_{t-1(BSESensex)} \quad (3)$$

Conclusions and implications of the study

The current study examined the short-run causal relationship and interdependency between two stationary time series data sets of stock markets (India and the United States) using the Granger causality test. The test results revealed that both markets are bidirectional in the short term. It suggests one time series is useful to predict future values of another time series.

In other words, the findings indicate that the Indian stock market causes the US stock market, and the US stock market causes the Indian stock market, demonstrating the interdependence of the two markets. Thus, this study explained that fund flow in one stock market (India or the United States) affects fund flow in another market. In the current study, independent regressors were used to quantify the dynamic cause and effect of BSE Sensex volatility spillover into NYSE volatility and S and P 500 volatility into BSE Sensex volatility.

The Granger causality test, which implies that both market indices are interdependent on one another, was employed to test this causal relationship in the short run. The test shows that S and P 500 volatility results from both BSE Sensex volatility and S and P 500 volatility. According to the study, financial system liberalization encourages money to move from market to market.

Thus, it reinforces the stock markets' interdependency. This study, however, emphasizes the nature of market linkages and emphasizes the importance of short-run causal relationships among markets for investment decision-making. These results are supported by the existing literature and provide the same line of thought about the interdependency between the stock markets.

This study gives the investor crucial information to reduce risk while diversifying the portfolio for investment purposes. This study's findings make it simpler for investors to create investment plans and fund diversification strategies to reduce portfolio risks. In fact, because of the ability to decrease portfolio risk through fund diversification across stock markets, stock market integration has become increasingly important for fund managers and investors in the age of globalization.

Furthermore, the bidirectional causal relationship suggests that investors will not benefit much from portfolio diversification in the short run when considering these markets due to higher risk on both linked and dynamically linked markets. The investors should hedge their portfolio by investing in another market.

Due to time and data constraints, the study only limited itself to the sample data period of 2001–2021 and applied the Granger causality model to measure short-run interdependency among the two stock market indices. The future research can also include various sample data to measure the interdependency of the stock markets, such as the types of global crises represented by the COVID-19 pandemic.

In addition to this, the researchers can also measure the cross-country interdependency in the long run with more recent models of econometrics such as VAR-BEKK-GARCH, GVAR, etc., The future studies can also include more emerging and frontier markets along with developed markets like the United States, Japan, and Europe to measure various types of market interdependency such as contagion effect, volatility spillover, correlation, and co-integration.

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