Cointegration and causality relationship of Indian stock market with selected world markets [version 1; peer review: awaiting peer review]

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Abstract

**Background:** The purpose of this study is to explore the trends and causes of established and emerging nations' stock market integration with India. The National Stock Exchange (NSE) indices act as a counterweight to international market indices. This study investigates the sustained interest of foreign investors in the Indian stock market in the wake of capital market reforms, as well as whether it moves in tandem with other markets in Asia and the United States.

**Methods:** Our study examined the possibility of cross-country cointegration between the largest economies and indices around the world using multiple financial econometric models, such as Augmented Dickey-Fuller, Unit Root, Correlation, and Johansen Cointegration.

**Results:** The findings of this study significantly support the notion that Indian and international financial markets are highly integrated. Vector error correction model indicates that the Indian market (NSE) is highly cointegrated with the US market (National Association of Securities Dealers Automated Quotations) and increased volatility signifies global contagion.

**Conclusion:** A cursory examination of the data reveals distinct investment and portfolio diversification options for global investors. This could assist regulators in formulating more effective rules regarding price discovery processes.

**Keywords**
Stock market, Investors, Volatility, Global market, Unit root test, VECM, Johansen cointegration test
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Introduction
An economic spiller occurs when one event sets off another event in a similar way, having an impact on economies both within and outside a country. In 2008, when Lehman Brothers collapsed in the U. S, the domino effect hit the economies worldwide including India (Aloui et al., 2016). Financial markets today are closely interconnected and driven by trust. Therefore, the developed and emerging markets have been a riveting field for the research of behavioural finance due to interlinked stock markets across the world. Lai et al. (2016) examined during the crisis, investors make errors of judgment as long as a group of investors takes irrational decisions that lead to worsening the situation of the stock market.

COVID-19 also delivered a shock to the economies of most countries, because of the nature of the interconnected global market (Karkowska & Urjasz, 2021). The Indian stock market has been broadly resilient amidst the COVID-19 crisis so far, despite the devastating waves of the pandemic (Kapoor et al., 2020). However, the Indian economy has witnessed some impact from the global crash. Seth & Panda (2020) discussed that it is hard to pinpoint exactly the impact of any financial crisis on the Indian stock market, but it seems that the COVID-19 crisis has spilled over into some sectors. Numerous studies (Shaikh, 2021; Dhall & Singh, 2020; Singh & Neog, 2020) have argued on insignificant causal linkage of the stock markets across the world. Some authors such as Zhang & Hamori (2021), have also focused on the possible factors and impacts of the global crisis on the Indian market. Several studies have identified both short-term and long-term cointegration and interconnected financial markets between different economies of the world (StawiarSKI, 2021; Yarovaya & Lau, 2016). The global financial markets are closely interconnected and driven by the emotions of the investors (Huang et al., 2020). Hence, this manuscript focuses a causal linkage and cointegration between the global crisis and the Indian stock. In previous studies such as Mukherjee & Bose (2008) and Rajwani & Mukherjee (2013), Asian economies have been integrated with the economies of developed nations such as Japan and the United States.

In this study, we contribute to the literature on strategic financial decision-making for investors. Using vector auto regressive correlation (VAR) and vector error correction method (VECM) to assess the cointegration, (Yarovaya & Lau, 2016). The global financial markets are closely interconnected and driven by the emotions of the investors. Several studies have identified significant causal linkage between the global crisis and the Indian stock. In previous studies such as Mukherjee & Bose (2008) and Rajwani & Mukherjee (2013), Asian economies have been integrated with the economies of developed nations such as Japan and the United States.

Literature review
A series of recent studies (Choudhary & Singhal, 2020; Kumar et al., 2021; Sahoo & Kumar, 2021; Kartal et al., 2022) has investigated the cointegration relationship of the stock market amid crisis. Some studies (He et al., 2020; StawiarSKI, 2021) have explained the causal linkage of Indian stock market with Asian countries while in some other studies, a number of authors have recognized the comprehensive analysis by applying Generalized Autoregressive Conditional Heteroskedasticity Model (Narasimha & Mushinada, 2020) and found very high volatility index of Indian stock market in comparison to developed countries during the COVID-19 crisis. While recent advances in the field of behavioural finance have highlighted the volatility clustering in the Indian stock market through the use of time series data analysis and predictive analytics. According to Khaing et al. (2020), stock trend extraction results matched genuine price movement. These patterns were retrieved with the news effect curve during the global recession 2008-2009. These criteria include timestamp conversion, identifying the necessary verb, stock reference, and identifying advanced trends. Chen (2021) created the new neural network model to develop the prediction model’s concepts. Belciug et al. (2021) evaluated the efficacy of a statistical learning framework using an algorithm based on a competitive/collaborative method for generating a reliable real-time forecast of the next stock market transaction price for a share during upswing of the market. Biswas et al. (2021) reviewed numerous models and approaches used in stock market prediction and focused on their advantages and disadvantages during the crisis. Numerous studies have argued that there is insignificant (Goudarzi & Ramanarayanan, 2011) and significant (Aggarwal & Raja, 2019) causal linkage among the stock markets across the world. Some scholars, such as Jain & Biswal (2016), have also focused on the possible drivers of rupee value decline and the influence of the 2014-2015 global crisis on the Indian stock market. The global financial markets are closely interconnected Muthukumaran et al. (2011) and driven by the emotions of the investors. Several studies have identified interconnected financial markets between different economies of the world during 1996-1997 crisis Yang et al. (2003) by applying VAR (vector auto-regression). Ahmad et al. (2005) have investigated only short term linkage whilst no significant linkage was found among the Indian Stock Market (NSE), Japanese (Nikkei) and US equity market (Dow Jones) amid crisis by using Granger-causality test. Menon et al. (2009) found that the Indian stock market did not have any causal linkage with the US and Japanese stock markets during the 2008 crisis period by hypothesizing Engle Granger test of co-integration. Siddiqui (2009) concluded that the Indian stock market is integrated with the global market. Some others studies such as Rajwani & Mukherjee (2013) have argued the Indian stock market is not interconnected with the Asian markets. Narayan et al. (2014) have investigated highly positive time varying bilateral correlations by analysing GARCH-dynamic conditional correlations.
index, which measures investor enthusiasm as opposed to investor fear. Previous studies have mainly exclusively used the State Bank of India and Infosys datasets. Elyasiani et al. proposed the GARCH model for heteroskedastic and volatile stock market crises (1995-2019) and effectively predicted stock market crises. He et al. studied the long-run cointegration equation of the Asian and the Indian market by applying the Johansen cointegration model. Some other studies have also confirmed the bidirectional causality of Bombay Stock exchange indices and US stock market indices by carrying out Granger causality test (Choudhary & Singhal, 2020). Seth & Panda (2020) revealed the strong dynamic linkage between the global economies and Indian economy by analysing the Autoregressive (AR1), Generalized Auto Regressive Conditional Heteroskedasticity (GARCH 1,1) Model and Asymmetric Dynamic Conditional Correlation (ADCC) model to determine the coupling and decoupling. Apart from analysing only the degree of cointegration and contagion among the world markets, several studies have hypothesized the global contagion on the volatility of Indian stock prices. Li et al. (2011) have confirmed that the GARCH model cannot completely account for all nonlinearity in simulated market amid global crisis. Goudarzi & Ramanarayanan (2011) have revealed the bilateral causality between the Bombay Stock Exchange and foreign institutional investors. Garg & Gulati (2013) examined the rationality of the Indian investors in the face of economic crisis and validated the use of rational pricing models. Ding et al. (2014) have indicated returns depend on the direction of the movement of buying and selling pattern and stock distinctiveness of individual holdings and on arbitrage constraint. Guyon (2014) suggested the models of path-dependent volatility provide excellent alternatives to the duopoly of local volatility and stochastic volatility that has dominated option pricing for the past twenty years.

The fractal structure has been studied by (Mahalingam & Selvam, 2014) with long term returns on the market. An adaptive multiplicative error model (MEM) with time-varying parameters was proposed by Härdle et al. (2015). A multiplicative error model (MEM) parameters are adaptively estimated through sequential testing. Bir et al. (2015) have investigated the highest volatility for open ended stocks in the Indian stock market. Kumar & Mahakud (2016) have explored the unidirectional causality between sentiment and stock market volatility. This study indicated that the market reacts more strongly to the impact or shock of negative or bearish mood than to positive or bullish sentiment. Boui et al. (2017) have examined significant hypothesis about the existence of cointegration linkage and nonlinear volatilities of oil and gold in Indian stock market during the crisis. Abuzayed et al. (2018) demonstrated that the skewed Student-t FIGARCH model generates the most precise VAR forecast for a single day. Other studies have demonstrated the ripple effects of United States of America uncertainty on other developed markets, such as L. Fang et al. (2018). Boako & Alagidede (2018) have confirmed the correlation amongst African stock markets, regional and global markets by carrying a comprehensive analysis. Chulal et al. (2018) have demonstrated that some crises have had a weak negative correlation with market synchrony. Wang et al. (2019) have confirmed that significant shocks have a substantial link with stock prices and that volatility is more susceptible to the asymmetric effect than extreme volatility. According to Xing & Yang (2019), firms that attract more individual investors provide higher returns with lower future stock price crash risk. It is widely accepted that a greater degree of correlation among stocks provides an early warning of the probability of crashes. It has been conclusively shown that herding is strongly evident during the fluctuations of market (Shantha, 2019).

Some studies such as Fang et al. (2020) also identified that the long-term volatility of the stock market depends upon many macroeconomic variables. Lyócsa & Molnár (2020) found that the autoregressive coefficient was negative during COVID-19 (November 2019 to May 2020) with but the stock market uncertainty and fear of virus highly affected the breath of the autoregressive coefficient amidst the COVID-19 crisis. Narasimha & Mushinada (2020) point out that investors are concerned about cognitive biases and therefore adapt to changing market dynamics. (Vo, 2020) studied the significant positive link between foreign investors and crash risk due to the asymmetry of information in the emerging market. Among BRICS (Brazil, Russia, India, China, and South Africa) a diverse responses to the stock market volatility reported including negative and positive shocks (Salisu & Gupta, 2020). Cui & Zhang (2020) have suggested that negative information creates fear among the investor which leads to a larger stock price crash risk. Nikkinen & Peltonmäki (2020) have focused on investors’ crash worries and utilised data on published newspaper articles and web search volumes to address the complex relationship between information supply and demand connected to investor anxiety and their consequences on realised stock market returns, implying and finding that the media contribute to the efficiency of the stock market by enhancing the transmission of information. He et al. (2020) have examined the futures markets ability to price discover by margin trading on the stock market. Kumar & Misra, (2020) have found widespread evidence of long-term similarity among the NIFTY 50 index and the global market. Naik et al. (2020) used GARCH (Generalized Autoregressive Conditional Heteroskedasticity) to calculate stock return error distribution. When time series data are heteroskedastic and volatile, the GARCH model is best. GARCH effectively predicted stock market crises (1995-2019) using State Bank of India and Infosys datasets. Elyasiani et al. (2021) analysed market greed by including the skewness index, which measures investor enthusiasm as opposed to investor fear. Previous studies have mainly exclusively...
explored the integration of Asian economies with other developed nations such as the United States and Japan during the period from 3rd January 2011 to 29th December 2017 in the midst of a global financial crisis. According to the literature, during the COVID-19 crisis, domino effects had both short-term and long-term negative consequences on economies all around the world (Salisu & Gupta, 2020).

However, there is a contradiction in the argument made by Aggarwal & Raja (2019); Rajwani & Mukherjee (2013) and Menon et al. (2009). Long-term cointegration of stock markets was not discovered, but correlation analysis revealed that stock market integration was growing with time.

Even though the majority of the COVID-19 economic crisis has passed, further research is still needed on the developed and rising Asian markets. In addition, it would be interesting to know whether the effect of the crisis on the Indian stock market persists over time and, if so, for how long. Do the recent shocks to global markets alter the standard deviation of forecasting errors in the Indian stock market? Contributing to existing theory and strategic financial decision-making for investors, this paper offers valuable insights. In particular, the authors explore how the global volatility index’s shock influences the Indian volatility index, how long the impact lasts, and the degree and sign of the effect.

Methods

In our study, we examined data from several major indices, including the NSE in India, the NIKKEI (Japan’s Nikkei 225 Stock Average) in Japan, NASDAQ (National Association of Securities Dealers Automated Quotations), DJI (Dow Jones Industrial Average) and S&P (Standard and Poor index) in the United States, the FTSE (Financial Times Stock Exchange) in the UK, the DAX (Deutscher Aktien Index) in Germany, the FTXIN (FTSE–Xinhua China A50 Index) in China, Cotation Assistée en Continu (CAC) benchmark of France stock market and the Hang Seng in Hong Kong. The descriptive statistics for all indexes’ returns are shown in Table 3. We compiled and collected the data from different websites (including Yahoo, Investing.com and NSE India) over the long-term, encompassing a significant portion of the recession from January 1, 2008, to December 2, 2021. The time period covered by the research has been selected to provide an in-depth look at the worldwide correlations that have an effect on the Indian stock market over the long term. Although the trading hours of each stock exchange varies, the time frame is the exact same for all indexes. Therefore, in order to examine the group statistics, we have taken the common sample. We calculated the daily return by applying the \[\text{Return} = \log \left( \frac{\text{Closing price of indices}}{\text{Closing price of indices (-1)}} \right)\] equation over the closing price. We analysed the data using the EViews 12 (University Version) software package. The student version of this software is freely available (https://eviews.com/download/student11/). The Johansen cointegration test (Menon et al., 2009) is used to demonstrate a long-term link between variables. To determine short-term and long-term associations between variables, the vector error correction model was utilised followed by Ezeibekwe (2021).

Hypothesis

\[H_0: \text{There is no long-term linear interdependency between the NSE index and the global index.}\]

\[H_1: \text{There is a long-term linear interdependency between the NSE index and the global index.}\]

Vector error correction model

This model is adopted when variables are cointegrated. VAR indicates the cointegration of the variables over the short term. In addition, by incorporating error correction terms, the model examines the long-term causal relationship. The number of variables can be measured by using the equations below. The vector autoregressive model of order 1 is called VAR (1):

\[x_{t,1} = \alpha_1 + \phi_{11}x_{t-1,1} + \phi_{12}x_{t-1,2} + \phi_{13}x_{t-1,3} + w_{t,1}\]  

(1)

\[x_{t,2} = \alpha_2 + \phi_{21}x_{t-1,1} + \phi_{22}x_{t-1,2} + \phi_{23}x_{t-1,3} + w_{t,2}\]  

(2)

\[x_{t,3} = \alpha_3 + \phi_{31}x_{t-1,1} + \phi_{32}x_{t-1,2} + \phi_{33}x_{t-1,3} + w_{t,3}\]  

(3)

Engle-Granger model is used to measure (Stawiarski, 2021) cointegration between the indices from the NSE and global indices such as Japan (NIKKEI), U.S. (NASDAQ, DJI, and S&P), UK (FTSE), Germany (DAX), China (FTXIN), Hong Kong (HANG SENG) and France (CAC). In 1981, Granger introduced the concept of cointegrated multivariate time

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1Menon et al. (2009) hypothesize that the Indian equity market have insignificant causal relationship with the US and Japanese equity markets during the crisis period by adopting the “Engle-Granger test” of co-integration. Yarovaya & Lau (2016) also examined the asymmetric causality test results supporting evidence of the coupling and decoupling hypothesis.
series to demonstrate linear combinations of stationary variables imply that there is a long-term relationship (Engle et al., 1987).

**Unit root test**

A regression model must have stationary conditions to prevent spurious regressions. Our study examines stationary conditions by using the ADF test (Augmented Dickey-Fuller) (Cheng et al., 2021). The null hypothesis is rejected if the ADF value (calculated) is less than the critical levels (1%, 5%, and 10%). The cointegration test follows the unit root test for measuring the extent of co-movement of long-term relationships among indices (Cheng et al., 2021).

**Johansen cointegration test**

In Johansen cointegration, the number of independent linear combinations (k) that give a stationary process is determined for (m) time series variables. The results are given as cointegration ranks. There is no cointegration relationship when the rank is 0, and there is a cointegration equation when the rank is 1, and so on. Johansen cointegration test analyses the relationship between the NSE index and global index by using Eigen-values and trace statistics. Integration is based on how many times a series need to be differentiated to produce a stationary series. The first difference generates an integrated series known as I (1). As a result, a time series with I (0) is stationary; if I (1), the level is stationary and the change is stationary. The equation below determines cointegration:

\[ P = m - k \]

Null Hypothesis; H0: When k = 0, then p = m, there is no linkage among the variables.

Alternate Hypothesis; H1: 0 < k < m, 0 < p < m There is a significant linkage among the variables.

**Descriptive statistical analysis**

Individual observations show large shifts during crisis times are further followed by large shifts in the return of the NSE indices and the global indices representing the wild and calm periods of volatility clustering. Figure 1 shows the clustering of the volatility for the daily return of indices, firstly noted by Mandelbrot & Taylor (1967) that large changes tend to be followed by large changes, of either sign, and small changes tend to be followed by small changes. Figure 2 represent the leptokurtic statistical distributions with kurtosis greater than three results to a greater extent of volatility because of positive or negative shocks in the stock market. While the Jarque-Bera of NSE daily return (32031.42) measures the high volatility. The shape of the curve and the value of kurtosis along with the low probability value reveal the possibility for the rejection of the null hypothesis. The skewness measures the asymmetry of a time series over a given period (normal skewness; 0, positive skewness; long right tail, negative skewness; long left tail).

Table 1 indicates that the left-hand tail of the German Blue chip stock market (DAX) is smaller than the right-hand tail. In other indices, a negative skewness (the left-hand tail is larger than the right-hand tail) indicates a scenario of small wins and few large losses for investors. Table 1 provides descriptive statistics on daily returns, highlighting Jarque-Bera standard deviation using the same sample for all indices. The NSE returns over the entire period sample shows a negatively skewed distribution of the sample (Jaque-Bera 33817.66, standard deviation 0.013768, Kurtosis 20.31397). In Japan, the statistical moments of the NIKKEI were Jarque-Bera 5525.19, standard deviation 0.0151, and Kurtosis 10.171. Jarque-Bera values for US Market (NASDAQ; 10447.74, standard deviation 0.014376, and Kurtosis 17.26778), (S&P; 23085.57, standard deviation 0.013164), and (DJI; 33669.34, standard deviation 0.012713, and Kurtosis 20.25097). These all show a similar leptokurtic distribution with negative skewness.

It is evident from the descriptive statistics that the significant value probabilities and the Jarque-Bera calculation indicate that the residual distribution of daily returns, like other indices (FTSE) Jarque-Bera 13203.88, standard deviation 0.012250 with Kurtosis value 13.81124), Germany (DAX) Jarque-Bera 9850.239, standard deviation 0.014335 with Kurtosis value 12.34726), Hong Kong (HANG SENG) Jarque-Bera 11642.69, standard deviation 0.0126 and Kurtosis 19.89 and France (CAC) Jarque-Bera 8553.046. The values of skewness and kurtosis observed the volatility clustering and specify the distribution of all indices (variables) is leptokurtic. Only Germany (DAX) is positively skewed, which specify that the huge gain covers the small losses of investors. The Indian stock market exhibits a positive correlation with

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2 A long-term equilibrium relationship between security margin trading and systemic risk volatility demonstrated by the Johansen co-integration test. (Zhao et al., 2019) Johansen’s cointegration test indicates an average relationship between the Indian and Shanghai stock markets and an especially strong relationship between the Indian and Singapore stock markets. A Granger causality test indicates that margin financing contributes to the volatility of systematic risk in a bear market.

3 Mukherjee & Bose (2008) posited cointegration, vector auto-regression, vector error-correction models, and Granger causality and found that the U.S. market leads all Asian markets in terms of information.
the world market, as seen in Table 2; however, the correlation of all variables is not strong enough to explain the cointegration.

Table 2 examines the correlation trends between the Indian market and a few selected global markets, indicating that there is a relationship between the Indian stock market and other markets; nevertheless, Figure 3 illustrates that this connection is sometimes parallel to the global economy.

It is said that the “flap of a butterfly’s wings in Brazil could set off a tornado in Texas” (Lorenz, 2000) that’s not true in the Indian context. The Indian stock market is still linked to the world market because the NSE has a positive correlation with all global indexes, despite the fact that this correlation has been reducing significantly.

Unit root test analysis
A unit root test determines whether a time series is stationary. The null hypothesis defines time series as having a unit root, while the alternative hypothesis defines them as being stationary. Table 3 indicates the value of t statistics in all variables exceeds the critical value.

In this case, these variables were tested again at a difference of one, and the result indicated a null hypothesis, i.e., that the series of all variables are integrated over four lag of order one. To perform Johansen’s cointegration test we employed the VAR lag order selection criterion. Table 4 identifies the AIC value at the third lag so we examined the cointegration test by using the third lag, recommended by AIC. A Japanese statistician (Akaike, 1974) developed the Akaike information criterion. It currently serves as a paradigm for the foundations of statistics and is also commonly employed for statistical inference. The Akaike information criterion (AIC) is an estimator of prediction error and, therefore, relative model quality for a given set of data. Given a set of data models, AIC determines the quality of each model in comparison to the other models. When a statistical model is employed to depict the process that generated the data, the representation is virtually
Table 1. Descriptive statistics (common sample) for daily returns of indices.

<table>
<thead>
<tr>
<th>Indices</th>
<th>RNSE</th>
<th>NIKKEI</th>
<th>NASDAQ</th>
<th>RS_P</th>
<th>RDJ</th>
<th>RDAX</th>
<th>RCAC</th>
<th>RFTSE</th>
<th>RFTXIN</th>
<th>RHNGSNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.0000289</td>
<td>-2.78E-06</td>
<td>0.000446</td>
<td>0.000233</td>
<td>1.000267</td>
<td>7.10E-05</td>
<td>-2.12E-05</td>
<td>-0.000141</td>
<td>-0.000198</td>
<td>-0.000198</td>
</tr>
<tr>
<td>Median</td>
<td>0.000523</td>
<td>0.000467</td>
<td>0.001137</td>
<td>0.000725</td>
<td>1.000697</td>
<td>0.000457</td>
<td>0.00359</td>
<td>-7.13E-05</td>
<td>0.000257</td>
<td>-0.000257</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.163343</td>
<td>0.077314</td>
<td>0.118493</td>
<td>0.109572</td>
<td>1.114020</td>
<td>0.105946</td>
<td>0.093842</td>
<td>0.091976</td>
<td>0.134068</td>
<td>0.134068</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.139038</td>
<td>-0.121110</td>
<td>-0.130032</td>
<td>-0.127652</td>
<td>-0.138418</td>
<td>0.877614</td>
<td>-0.130983</td>
<td>-0.115124</td>
<td>-0.094210</td>
<td>-0.135820</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.013768</td>
<td>0.015108</td>
<td>0.014376</td>
<td>0.013164</td>
<td>0.012713</td>
<td>0.014335</td>
<td>0.014673</td>
<td>0.012250</td>
<td>0.016678</td>
<td>0.014561</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.260881</td>
<td>-0.804981</td>
<td>-0.377227</td>
<td>-0.560404</td>
<td>-0.532429</td>
<td>0.078381</td>
<td>-0.162182</td>
<td>-0.258883</td>
<td>-0.146751</td>
<td>-0.044138</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>20.31397</td>
<td>10.17399</td>
<td>12.59833</td>
<td>17.26778</td>
<td>23085.57</td>
<td>13203.88</td>
<td>2086.079</td>
<td>11642.69</td>
<td>13.16324</td>
<td></td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>33817.66</td>
<td>5525.193</td>
<td>10447.74</td>
<td>23085.57</td>
<td>13203.88</td>
<td>2086.079</td>
<td>11642.69</td>
<td>13.16324</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probability</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>0.781056</td>
<td>-0.006825</td>
<td>1.205285</td>
<td>0.629246</td>
<td>0.192009</td>
<td>-0.057399</td>
<td>-0.380466</td>
<td>-0.534839</td>
<td>0.573315</td>
<td></td>
</tr>
<tr>
<td>Sum Sq. Dev.</td>
<td>0.512570</td>
<td>0.559675</td>
<td>0.558820</td>
<td>0.468555</td>
<td>0.405798</td>
<td>0.752146</td>
<td>0.573315</td>
<td>0.573315</td>
<td>0.573315</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
<td>2705</td>
</tr>
</tbody>
</table>

Source: author’s calculations.

Table 2. Correlation matrix for the daily returns of indices.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>RNSE</th>
<th>NIKKEI</th>
<th>NASDAQ</th>
<th>RFTXIN</th>
<th>RDAX</th>
<th>RHNGSNG</th>
<th>RFTSE</th>
<th>RDJ</th>
<th>RCAC</th>
<th>RS_P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNSE</td>
<td>1.000</td>
<td>0.384</td>
<td>0.259</td>
<td>0.287</td>
<td>0.426</td>
<td>0.567</td>
<td>0.441</td>
<td>0.324</td>
<td>0.423</td>
<td>0.322</td>
</tr>
<tr>
<td>RNIKKEI</td>
<td>0.384</td>
<td>1.000</td>
<td>0.141</td>
<td>0.330</td>
<td>0.345</td>
<td>0.600</td>
<td>0.373</td>
<td>0.188</td>
<td>0.366</td>
<td>0.181</td>
</tr>
<tr>
<td>RNASDAQ</td>
<td>0.259</td>
<td>0.141</td>
<td>1.000</td>
<td>0.113</td>
<td>0.571</td>
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<td>0.519</td>
<td>0.876</td>
<td>0.544</td>
<td>0.931</td>
</tr>
<tr>
<td>RFTXIN</td>
<td>0.287</td>
<td>0.330</td>
<td>0.113</td>
<td>1.000</td>
<td>0.183</td>
<td>0.563</td>
<td>0.208</td>
<td>0.110</td>
<td>0.193</td>
<td>0.116</td>
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<tr>
<td>RDAX</td>
<td>0.426</td>
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<td>0.571</td>
<td>0.183</td>
<td>1.000</td>
<td>0.407</td>
<td>0.848</td>
<td>0.646</td>
<td>0.921</td>
<td>0.643</td>
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<td>0.563</td>
<td>0.407</td>
<td>1.000</td>
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<td>0.273</td>
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<td>0.612</td>
<td>1.000</td>
<td>0.627</td>
<td>0.976</td>
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<tr>
<td>RCAC</td>
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<td>0.544</td>
<td>0.193</td>
<td>0.921</td>
<td>0.402</td>
<td>0.894</td>
<td>0.627</td>
<td>1.000</td>
<td>0.624</td>
</tr>
<tr>
<td>RS_P</td>
<td>0.322</td>
<td>0.181</td>
<td>0.931</td>
<td>0.116</td>
<td>0.643</td>
<td>0.273</td>
<td>0.606</td>
<td>0.976</td>
<td>0.624</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Source: author's calculations.
Figure 3. Movement of indices.

Table 3. Augmented dickey-fuller test statistic.

Null Hypothesis: D (R indices) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on AIC, max.lag=2)

<table>
<thead>
<tr>
<th>Augmented Dickey-Fuller test statistic</th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (RNSE)</td>
<td>-49.54543</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (RNIKKEI)</td>
<td>-49.86084</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (NASDAQ)</td>
<td>-55.14356</td>
<td>0.0002</td>
</tr>
<tr>
<td>D (RHNGSNG)</td>
<td>-57.60954</td>
<td>0.0031</td>
</tr>
<tr>
<td>D (RFTXIN)</td>
<td>-56.95976</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (RFTSE)</td>
<td>-61.81385</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (RDJI)</td>
<td>-54.49088</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (RDAX)</td>
<td>-59.06823</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (RCAC)</td>
<td>-61.97524</td>
<td>0.0001</td>
</tr>
<tr>
<td>D (RS_P)</td>
<td>-54.97958</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Test critical values: 1% level -3.432586
5% level -2.862414
10% level -2.567280

Source: author's calculations.

Table 4. VAR Lag order selection criteria.

Endogenous variables: RS_P RNSE RNIKKEI RNASDAQ RHNGSNG RFTXIN RFTSE RDJI RDAX RCAC
Exogenous variables: C

<table>
<thead>
<tr>
<th>Lag</th>
<th>Log L</th>
<th>LR</th>
<th>FPE</th>
<th>AIC</th>
<th>SC</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21099.53</td>
<td>NA</td>
<td>1.35e-42</td>
<td>-68.03073</td>
<td>-67.95928</td>
<td>-68.00295</td>
</tr>
<tr>
<td>1</td>
<td>21497.50</td>
<td>781.8252</td>
<td>5.16e-43</td>
<td>-68.99193</td>
<td>-68.20601*</td>
<td>-68.68644*</td>
</tr>
<tr>
<td>2</td>
<td>21620.40</td>
<td>237.4761</td>
<td>4.79e-43</td>
<td>-69.06580</td>
<td>-67.56542</td>
<td>-68.48259</td>
</tr>
<tr>
<td>3</td>
<td>21721.71</td>
<td>192.4845</td>
<td>4.77e-43*</td>
<td>-69.07002*</td>
<td>-66.85516</td>
<td>-67.20909</td>
</tr>
<tr>
<td>4</td>
<td>21802.79</td>
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<td>129.8028</td>
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<td>-65.27074</td>
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<tr>
<td>6</td>
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<td>187.0576</td>
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<td>-64.56831</td>
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</tr>
<tr>
<td>7</td>
<td>22079.51</td>
<td>181.1104</td>
<td>5.52e-43</td>
<td>-68.93390</td>
<td>-63.86115</td>
<td>-66.96209</td>
</tr>
<tr>
<td>8</td>
<td>22171.27</td>
<td>159.5397*</td>
<td>5.70e-43</td>
<td>-68.90731</td>
<td>-63.12009</td>
<td>-66.65778</td>
</tr>
</tbody>
</table>

Source: author's calculations.
LR: sequential; modified LR test statistic; FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.
*Indicates lag order selected by the criterion (each test at 5% level).
### Table 5. Johansen’s cointegration test.

**Lags interval (in first differences): 1 to 3**

#### Unrestricted cointegration rank test (Trace)

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigen-value</th>
<th>Trace statistic</th>
<th>0.05 Critical value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>None *</td>
<td>0.334300</td>
<td>3261.797</td>
<td>239.2354</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 1 *</td>
<td>0.285750</td>
<td>2753.151</td>
<td>197.3709</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 2 *</td>
<td>0.268835</td>
<td>2332.498</td>
<td>159.5297</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 3 *</td>
<td>0.231890</td>
<td>1941.102</td>
<td>125.6154</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 4 *</td>
<td>0.222216</td>
<td>1611.324</td>
<td>95.75366</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 5 *</td>
<td>0.212214</td>
<td>1297.192</td>
<td>69.81889</td>
<td>0.0000</td>
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<tr>
<td>At most 6 *</td>
<td>0.206747</td>
<td>999.0299</td>
<td>47.85613</td>
<td>0.0000</td>
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<tr>
<td>At most 7 *</td>
<td>0.190017</td>
<td>709.5135</td>
<td>29.79707</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 8 *</td>
<td>0.170580</td>
<td>446.0860</td>
<td>15.49471</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 9 *</td>
<td>0.156201</td>
<td>212.3006</td>
<td>3.841465</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Trace test indicates 10 cointegrating eqn(s) at the 0.05 level.

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigen value</th>
<th>Max-Eigen Statistic</th>
<th>0.05 Critical value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>58.43354</td>
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</tr>
<tr>
<td>At most 2 *</td>
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<td>391.3954</td>
<td>52.36261</td>
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<tr>
<td>At most 3 *</td>
<td>0.231890</td>
<td>329.7780</td>
<td>46.23142</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 4 *</td>
<td>0.222216</td>
<td>314.1328</td>
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<td>263.4275</td>
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<tr>
<td>At most 8 *</td>
<td>0.170580</td>
<td>233.7855</td>
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</tr>
<tr>
<td>At most 9 *</td>
<td>0.156201</td>
<td>212.3006</td>
<td>3.841465</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Max-eigenvalue test indicates 10 cointegrating eqn(s) at the 0.05 level.

Source: author’s calculation.

*Denotes rejection of the hypothesis at the 0.05 level.


Figure 4. Impulse response functions (Source: authors calculations).
### Table 6. Unrestricted cointegrating coefficients (normalized by $B'S11*B=I$).

<table>
<thead>
<tr>
<th>Unrestricted Cointegrating Coefficients (normalized by $b'<em>S11</em>b=I$): PANEL A</th>
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<tbody>
<tr>
<td><strong>RNSE</strong></td>
</tr>
<tr>
<td>24.65992</td>
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<tr>
<td>2.437710</td>
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<td>86.06294</td>
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</table>

<table>
<thead>
<tr>
<th>Unrestricted Adjustment Coefficients (alpha): PANEL B</th>
</tr>
</thead>
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<tr>
<td><strong>D (RNSE)</strong></td>
</tr>
<tr>
<td>0.000223</td>
</tr>
<tr>
<td>0.000305</td>
</tr>
<tr>
<td>-0.000253</td>
</tr>
<tr>
<td>0.002884</td>
</tr>
<tr>
<td>0.000967</td>
</tr>
<tr>
<td>0.003160</td>
</tr>
<tr>
<td>0.000590</td>
</tr>
<tr>
<td>-0.000487</td>
</tr>
<tr>
<td>-0.000270</td>
</tr>
<tr>
<td>-0.000350</td>
</tr>
</tbody>
</table>

| 1 Cointegrating Equation(s): Log likelihood | 41945.85 |
|-------------------------------------------------|
| Normalized cointegrating coefficients (standard error in parentheses) |
| **RNSE** | **RNKKEI** | **RNASDAQ** | **RDAX** | **RFTXIN** | **RHNGSNG** | **RFTSE** | **RDJI** | **RCAC** | **RS_P** |
| 1.000000 | -0.899109 | -1.137781 | -0.433553 | 0.256508 | -1.503849 | -0.733263 | -5.489252 | -2.491691 | 12.25514 |
| (0.18129) | (0.39565) | (0.33892) | (0.11866) | (0.20640) | (0.34232) | (0.68768) | (0.38612) | (0.93717) | |
never perfect; as a result, some information is lost. AIC assesses the relative amount of information lost by a particular model; the less information a model loses, the higher the model’s quality.

**Results**

**Johansen’s cointegration test results**

Table 5 shows the statistical values of Johansen’s cointegration test. In addition, it provides information about the maximum Eigen-value. Statistics for all variables dependent (NSE) and independent (World’s indices) demonstrate a perfect correlation of cointegration. Since the calculated value of statistics and maximum Eigen-value are greater than the critical value (at 5% level) of (MacKinnon et al., 1999), the null hypothesis of no cointegration is rejected in favour of the alternative hypothesis of cointegration. Therefore, the Indian stock market and the global stock market have ten cointegration equations.

In Figure 4, we show impulse response functions associated with the non-factorized one standard deviation of innovations for the Indian stock market and the stock markets of some of India’s top trading partners and developed nations. It depicts the negative impulse responses of the Chinese and Japanese stock markets. Interestingly, both markets are responding similarly to a shock to the Indian stock market in their respective stock markets. Geographic proximity may be the reason for this. The established stock markets of the United States and other economies have a distinct trend. It demonstrates that these markets are in fact developed and have a robust positive impulse reaction to the Indian stock market.

**Empirical results**

This study shows innovations in the Indian stock market do indeed propagate to India’s top trading partner’s stock markets in a time-varying manner. In this study, the U.S. stock market appears to be the most influential. The analysis of the ADF statistics (Table 3) confirmed the unit root series for all indices and then we determined lag order using the VAR Lag Order Selection Criteria (Table 4) to carry out causality test. To perform the cointegration test, we selected the AIC, indicating the third lag. Table 5 reveals the critical value is less than trace statistics and Max-Eigen values, which rejects the null hypothesis of no causal links, resulting in cointegration equations among all variables. Panel C of Table 6 predicts the long-term cointegration equation for the Indian stock market, which suggests that Japan (NIKKEI), US (NASDAQ, DJI, UK (FTSE), Germany (DAX), Hong Kong (HANG SENG) and France (CAC) indices have a positive correlation with Indian Indices (NSE), while China (RFTXIN) and US (S&P) indices have a negative correlation, considering ceteris paribus on Indian stock market. As Song et al. (2021) have documented supporting evidence, our findings are consistent with the idea that global financial crises have positively influenced interdependence of stock markets in Asian countries. Based on the coefficients, the linkage between the Indian stock market and the global market is statistically significant at a 1% level. Additionally, the Chinese stock market indices and S&P show a negative impact on Indian stock markets and the NASDAQ and Dow Jones indices in the US, Hong Kong (HANG SENG), and Japan (NIKKEI) have shown the strongest long-term correlation with Indian markets. The impulse reaction of NIKKEI to unit shock in NSE causes a little decrease in NSE on days 3 and 4, but an increase on day 6. Between days 8 and 10, this effect increases marginally. Similarly, when a unit shock is applied to NSE, NIKKEI displays a mixed reaction. This is evidence that the Japanese and Indian stock markets are not fully integrated. The impulse response of S&P to a unit shock on the NSE demonstrates that it has a negative impact on the SENSEX on the second day and a positive impact on the third day. It indicates that the NSE is highly cointegrated with the S&P and in the same way, DJI, NASDAQ, FTSE, and CAC. In addition, HNGSNG, DAX, and FTXIN do not have a significant impact on the Indian stock market. Similar findings are reported by Choudhary & Singhal (2020) and Mukherjee & Bose (2008). The correlation results are consistent with Seth & Panda (2020) indicated that the Indian stock market index has a strong positive correlation with the US stock market index.

**Conclusion**

The empirical findings suggest that the selected stock markets have a long-term dynamic. According to our research, the volatility of the US stock market considerably affected the Indian stock market. We performed a vector error correction model test to assess the stationary conditions of the series. This test demonstrated that the sequence is stationary. However, the variables become constant after taking into account the original difference. Cointegration tests show that the Indian stock market is integrated over time owing to the presence of a cointegration vector. A model of error correction demonstrates conclusively that variables are causal in the long-term. The stock market in India is impacted by those in the United States, Great Britain, Japan, and Germany. In addition, we applied the pairwise Granger causality test, which reveals the lead-lag connection across the markets, to test for short-term causative and informational linkages among diverse pairs of markets. According to our findings, the Indian stock market is neither fully connected nor completely decoupled from the global market. Nonetheless, the amount of integration implies that portfolio diversification can still result in substantial risk reduction and return maximisation in both the short-term and long-term by diversifying their portfolio during a crisis. In recent years, the returns on major US stock indices have dominated the returns for Indian stocks. Similar results show that the bank-dominated financial sectors of the ASEAN five and China are increasingly integrated (Caporale et al., 2021).
The study is prone to various limitations because it relies on secondary sources of data, which have inherent limitations, such as the total number of trading days during the study period for each country were different. So, the sample was adjusted with the help of EViews software. A quick glance at the study highlights clear-cut investment and portfolio diversification opportunities for international investors. This may help regulators formulate better policies concerning price discovery mechanisms. Moreover, it is possible to extend the present study to include global contagion issues between the sample countries. This could be done using high frequency data.

Data availability

This project contains the following underlying data:

- CHINA A 50(FTXIN9).xlsx
- DAX.xlsx
- NIKKEI.xlsx
- NSE.xlsx
- S&P 500.xlsx
- CAC 40 (FCHI).xlsx
- DJI.xlsx
- HANG SENG.xlsx
- NASDAQ 100.xlsx
- FTSE.xlsx

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

References
Chen S. Correlation analysis of financial indicators and stock price fluctuations based on artificial intelligence system. 2021 International Conference on Artificial Intelligence and Smart Systems (ICAISS). 2021; 43-46.


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