Eurasian Journal of Business and Economics, 15(30), 45-61, (2022).

Contagion Effects of Covid-19 on Select Stock Market Indices

Smita RAMAKRISHNA[*], Gopalakrishnan KALPAKAM[**],

Received: June 30, 2022. **Revised:** October 16, 2022. **Accepted:** November 23, 2022.

Abstract

We examine the impact of the COVID-19 pandemic on the interlinkages between the Indian stock market and some of the largest indices across the world. We compare the co-movements of these stock markets to identify the possibilities for international portfolio diversification. We use the Johansen cointegration technique and Vector Error Correction Mechanism to understand the nature of long-run and short-run cointegration. We also apply the Impulse Response Function to understand the time effects of the shock. The results of the Johansen cointegration test indicate that there is an increased level of cointegration among the stock market indices post the pandemic. Our results of VEC Block Exogeneity Wald Tests indicate that in the pre-Covid time, there were linkages between the stock markets of India and the U.K., Japan, and Hongkong. However, the post-pandemic results indicate the shock transmission effects from India to two very important European indices, i.e., the U.K. and Euronext stock exchanges, and to the stock market of Japan. We also observe transmission effects from the USA to India post-Covid period.

Keywords: *Cointegration, VECM, Covid-19, Impulse Response Function, Portfolio diversification*

JEL Code**:** *F3, G1, G11, G15*
UDC: 3319
DOI: https://doi.org/10.17015/ejbe.2022.030.03

[*] Associate Professor, K J Somaiya Institute of Management, India. E-mail: smitaramakrishna@somaiya.edu

[**] Associate Professor, K J Somaiya Institute of Management, India. E-mail: kalpakam@somaiya.edu

1. Introduction

There was a huge fall in the major indices of the world, such as FTSE (Financial Times Stock Exchange 100 Index from the UK), SENSEX (Bombay Stock Exchange from India), Nikkei (Japan), NYSE (New York Composite Index from the US), etc. with an increase in the number of Covid-19 cases in the early period of 2020. The pandemic affected economies of the world and its financial systems, including stock markets, reported IMF in its Financial Stability Report (April 2020). In March 2020, The World Health Organization (WHO) announced the coronavirus disease (COVID-19) outbreak as a pandemic. A lockdown was imposed, and most people worldwide had to be confined to their homes with fear; people resorted to panic buying, and businesses and factories were closed (Ramelli and Wagner, 2020). The virus is one of the biggest threats to the nations of the global economy. The World Bank, in April 2020, described the global decline as the worst since the Great Depression of the 1930s. Many disruptions worked in tandem where Governments of various countries-imposed mobility restrictions, which affected bilateral trade and a severe shock to the supply side, as well as lowered the demand on the other. Wren-Lewis (2020) observes that due to a considerable reduction in the production side and change in consumer demands, the COVID-19 pandemic could significantly affect the GDP.

In this paper, we explore the empirical evidence of contagion pre- and post-COVID-19 between the Indian stock index and the major world stock indices, representing 60-80% of stocks of the respective exchanges with top capitalisation and therefore assume importance in the world economy. Jeon and von Frustenberg (1990) observed that the pace of stock market integration accelerated post-1987 crash. Indian stock market offers an attractive investment opportunity with good returns at attractive valuations combined with the benefit of growth in the future. In 2020, India could attract a fair share (INR 170260 crores as per Central Depository Services (India) Limited-CDSL) of emerging market inflows due to a better-than-expected economic recovery with a supportive policy framework. It is one of the world's top ten stock markets, with a market capitalisation of over USD 3 trillion (May 2021). Our empirical study is of great interest, given that Indian stocks are traded at inexpensive valuations compared to developed markets. The results in the paper have important implications for portfolio diversification and minimizing the associated risk. Trade relations affect foreign exchange reserves and the exchange rate and, therefore, the balance of payments. A study of this kind assumes importance in the wake of the COVID-19 pandemic, where the business models have undergone a change impacting the bottom lines of companies and stock markets. Economies worldwide are prone to external shocks and crises, wherein information from studies of this kind can help policymakers make better decisions.

Driessen and Laeven (2007) found that international diversification benefits are much higher for emerging markets. Baele and Inghelbrecht (2009) made a point for international diversification over industry diversification. International diversification scores over other types of diversification, and it helps even in a

contagion where the magnitude of the impact may not be the same for all countries. Earlier studies observed that in any financial crisis impacting many economies worldwide, stock market interlinkages increase and spread quickly (Forbes and Rigobon, 2002). Kasa (1992) concluded that gains by diversification inequities are possible in the short run, which gets wiped out in the long run. India, an emerging market with stocks available at good valuations, attracts good foreign investments; therefore, this study assumes importance.

COVID-19 is the worst contagion widespread in impact and spread over a long period after the global financial crisis of 2008. There are notable studies by Boubaker et al. (2016), Habiba et al. (2019), and Gulzar et al. (2019) analysed the interlinkages between several stock markets of the world. Still, there are very few studies worldwide on the impact of the COVID-19 pandemic. The impact of many other crises was local or, at best, confined to a few economies. Ramelli and Wagner (2020) examined the impact of COVID-19 on US markets, Zeren and Hizarci (2020) examined co-movements of European and Asian stock markets, while Senol and Zeren (2020) examined G7 countries and European stock markets. Considering the top 21 stock indices of the world, Liu et al. (2020) found that the Asian markets reacted more negatively than the other markets. These are studies worldwide on various developed and emerging stock markets. They include a short period of three months during the fall in the markets, but surprisingly, all the markets have quickly risen at the same speed to reach newer heights. Our study takes the fall and rise of the markets, although businesses have yet to return to normal.

Bhunia and Ganguly (2020) have included India in their study and examined volatility and leverage effects pre- and post-COVID-19 of selected countries of the world and not the co-movements required in portfolio diversification. Chakrabarti et al. (2021) studied the G20 countries. None of these studies are with specific references to India. India is one of the prominent Asian countries attracting a huge share of inflow inwards; it is of paramount importance to Indian policymakers and foreign portfolio managers across the world. Our study examines specifically concerning interlinkages and their causality from and to the Indian stock market with the major indices of the world for the pre-and post-COVID-19 period, which has not been studied before.

Our results of the Johansen cointegration test indicate a higher number of long-run cointegrating equations among the BSE -SENSEX and other six stock markets in the post-Covid period. The reason for long-run cointegration among the chosen markets could be because there are greater inter-dependencies among the economies. The results of VEC Block Exogeneity Wald Tests indicate that in the pre-COVID time, there were linkages between India's stock markets, the UK, Japan, and Hongkong. There is unidirectional causality from the UK to India, while the Indian stock market leads the two Asian indices. However, the post-pandemic results indicate the shock transmission effects from India to two very important European indices, i.e., the U.K. and Euronext stock exchanges, and also to the stock market of Japan. We also see

transmission effects from the US to India in the post-Covid period. A possible reason for such linkages could be due to the cross-holdings in stocks across these countries.

The increased inter-linkages make portfolio diversification a challenge. In the pre-covid period, there was an absence of causality between India and the US, Europe, and China, providing scope for diversification. In sharp contrast, post the pandemic, India does not have short-run linkages only with the stock markets of Hongkong and China, providing scope for investing in these markets. Overall, we conclude that there is evidence in our data to suggest both long-run and short-run cointegration among the stock markets, to a greater extent, in the post-pandemic period. The results of our study are in line with similar comparative studies (Gulzar et al., 2019; Boubaker et al., 2016), which examined the impact of the 2008 financial crisis on the stock markets.

The rest of the paper is organized as follows. Section 2 reviews research related to the crisis across the world resulting in financial contagion and also other pandemics across the world. Section 3 is about the data and methodology, followed by empirical results and discussion in Section 4. Section 5 is about the conclusions of our paper providing policy recommendations.

2. Literature Review

A significant transformation in portfolio management recognizes that creating an optimum investment portfolio combines several unrelated securities and reduces risk by diversifying a portfolio. Markowitz (1952), in his Modern Portfolio Theory (MPT), observed that a diversified portfolio is less volatile than the absolute risk of its securities. A low covariance between individual securities lowers the overall portfolio risk rather than the risk of each asset. Likewise, stocks from different countries with low covariance are desirable. Still, after a crisis like the COVID-19 pandemic, when the systematic risk increases, it may not provide any risk cover due to the contagion effect. A portfolio resilient to negative economic forces helps in consistent returns. In the aftermath of a contagion, systemic factors are common to interconnected markets but may not have the same impact on all markets. Therefore, it helps to diversify the portfolio across countries which is possible with advancements in technology.

Levy and Sarnat (1970) built on Markowitz's portfolio theory for international portfolio diversification. Further, Solnik (1974) proved, using the I-CAPM model, that an internationally diversified portfolio can eradicate idiosyncratic risks present in a portfolio with only domestic financial assets. On the contrary, Chen et al. (1986) argued that whenever systematic news influences a particular asset, as in a contagion, no extra profit can be earned based on efficient market theory and rational expectations intertemporal asset pricing theory since the security prices fully reflect all available information. The stock markets of the world, developed and developing countries, are becoming more and more closely interlinked (Wong et al., 2005). Therefore, over the last decade, investors have been reaping diminishing

returns on an international portfolio compared to market history (Srivastava, 2007). Moreover, in the event of any financial crisis affecting many economies worldwide, stock market interlinkages increase and spread very fast (Forbes and Rigobon, 2002).

There are other studies on the diversification of portfolios. Driessen and Laeven (2007) found that international diversification benefits are much higher for emerging markets. Baele and Inghelbrecht (2009) made a point for international diversification over industry diversification. International diversification scores over other types of diversification, and it helps even in a contagion where the magnitude of the impact may not be the same for all countries.

The earliest studies of Grubel (1968), Levy and Sarnat (1970), Granger and Morgenstern (1970), and Ripley (1973) studied market co-movements and interdependence using correlation analysis. They examined the short-run linkages between stock indices of different countries across the globe. Later, in order to study the long-run benefits of international portfolio diversification, Kasa (1992) used cointegration analysis. The study concludes that gains by diversification into equities are possible in the short run, which gets wiped out in the long run. Researchers across the world used cointegration (Habiba et al., 2019; Gulzar et al., 2019; Bhuyan et al., 2010); the vector error correction model (V.E.C.M.) has been applied by Bhattacharya and Samanta (2001) and Gulzar et al. (2019); G.A.R.C.H.-B.E.K.K. model by Gulzar et al. (2019), EGARCH models by Habiba et al. (2019), Detrended Cross-Correlation Analysis (DCCA) by Chakrabarti et al. (2021) along with the network and complexity theories. There is sufficient evidence of increased contagion risk during periods of stress in the extant literature, irrespective of the method used to study international portfolio diversification (Yarovaya et al., 2020).

Boubaker et al. (2016) studied the subprime crisis of 2008. Their study links the US markets with other developed and emerging markets before and after the crisis. They find a higher causality between the markets after the crisis and more short-term co-movements with higher error correction coefficients for the markets. Similarly, Habiba et al. (2019) found a long-term integration between the US and South Asian markets and a significant volatility spillover from the US to Sri Lanka and India but not Pakistan. Gulzar et al. (2019) also found a long-term cointegration between the US and emerging stock markets during the subprime crisis of 2008. The VECM and impulse response function reveals that a shock in the US market has a short-term impact on emerging markets. COVID-19 is the biggest crisis impacting the entire world after the subprime crisis of 2008, and this study examines its impact on the major stock markets of the world pre- and post-crisis.

There are studies on the impact of a health crisis on stock markets, and they are limited. According to Bhuyan et al. (2010), the outbreak of SARS in 2003 increased the cointegration and co-movements between the infected countries. Pandemic influenza A (H1N1) in 2009 coincided with the financial crisis of 2008-09. Peckham

(2013) argued that it is essential to understand the entanglement of financial and biological contagion to gain insights into global interconnectedness.

According to WHO, epidemics that influence many people significantly affect economies worldwide, e.g., Influenza, Ebola, and severe acute respiratory syndrome (SARS). With the onset of SARS, articles in the popular press, news channels, and business newspapers reported a tremendous setback to the countries affected worldwide. Contrary to these reports, Keogh-Brown and Smith (2008) studied the epidemic's effect (SARS) and reported that the epidemic did not affect the economy and investment. In another study on the Hong Kong economy, Siu and Wong (2004) found a temporary and significant effect of SARS.

There are very few studies worldwide on the impact of the COVID-19 pandemic. Ramelli and Wagner (2020) claimed that due to the COVID-19 pandemic, the stock prices in US firms were adversely affected, and there is very high volatility in the stock prices. Zeren and Hizarci (2020) examined co-movements of European and Asian stock markets with daily data from January to March. They found a cointegration of KOSPI (South Korea), SSE (China), and IBEX35 (Spain) indices. They reveal that there was no cointegration relationship with the indices of FTSE MIB (Italy), CAC40 (France), and DAX30 (Germany). Senol and Zeren (2020) examined G7 countries and European stock markets between January 21 and April 7, 2020 and observed a long-run relationship during this pandemic period. Ashraf (2020), in his study on the impact of the rise in coronavirus cases on the stock market prices of 64 countries, found a negative relationship during the three months between the last week of January till April 2020. Jelilov et al. (2020) found that the rising COVID-19 accentuates the negative shock and distorts the positive relationship between inflation and stock market returns. Mahajan and Mahajan (2021) reported that gold returns in India have a negative beta with stock market returns during the COVID period and are not caused by negative stock market returns. The Granger causality and VAR test results reveal that lagged gold returns cause Nifty returns and that gold price has significant information to forecast stock prices.

We review past Indian studies and the relationship between Indian stock markets and other stock markets worldwide during tranquil periods, as in a pre-COVID-19 scenario. Bhattacharya and Samanta (2001), using the daily data and the cointegration and error correction model, concluded that BSE Sensex is dependent on NASDAQ news. Wong et al. (2005), using weekly prices with the Granger causality and cointegration method, found a short-run and long-run relation between the Indian stock market and the major developed countries' stock markets (the US, the UK, and Japan). There is cointegration between the Indian stock markets and the Chinese and US stock markets, conclude Chen et al. (2006). Tripathi and Sethi (2010) studied major world markets using data from 10 years between 1998 and 2008. They conclude that the US stock market is cointegrated with Indian markets but not China, UK, and Japanese markets.

Das and Gupta (2021) studied the top five countries with COVID infection in varying political zones or economic statuses. They reported that before COVID, they were not cointegrated, while the results reveal cointegration during and after the pandemic. They also report that the three countries least COVID-infected did not show any integration during the pandemic.

There are studies on Indian stock markets with Asian countries during tranquil periods. Studies on the cointegration of Indian stock markets with Asian markets such as Malaysia, China, South Korea, Taiwan, Japan, Indonesia, and Hong Kong suggest that the Indian stock market was not cointegrated with the Asian markets (Rajwani and Mukherjee, 2013). They used data for a long period from 1991 to 2011 and suggested that a possible reason is due to macroeconomic structural differences and concluded that Indian markets are insensitive to any news from these countries, while Saha and Bhunia (2012) found both short-run and long-run relationship between Indian stock indices and select countries in South Asia.

Bhunia and Ganguly (2020) examined volatility and leverage effects pre- and post-COVID. Their results reveal that German and Indian stock prices are the most volatile, while the UK, the US, and Russian markets are the least volatile. Chakrabarti et al. (2021) found that the emerging markets of G20 are not integrated, while the advanced countries showed a strong network before the pandemic. With the outbreak of COVID-19, all the advanced and G20 countries, except China, show that they are strongly connected due to the contagion. No studies compare Indian markets with the world's top indices in the COVID period. Our study examines the cointegration of the Indian stock market with the world's major indices for the pre- and post-COVID-19 period.

To the best of our knowledge, there are very limited studies on the cointegration of Indian markets with other major markets of the world pre- and post-COVID-19. This study aims to identify the co-movement of Indian stock markets with other top indices of the world pre- and post-COVID-19. The other objective is to ascertain the causal linkages among the stock markets pre and post Covid-19. In short, we wish to examine the change in the stock market linkages arising due to COVID-19 to aid in investment planning and policy formulation.

3. Data and Methodology

3.1. Data

BSE (Sensex of the Bombay Stock Exchange from India), NYSE (New York Composite Index from the US), FTSE (Financial Times Stock Exchange 100 Index from the UK), HANG SENG (HSI from Hong Kong), EURONEXT (100 Index pan Europe), SSE (Shanghai Composite Index from China) and NIKKEI (225 of Japan).

We use the daily closing prices of stock market indices of SENSEX (Bombay Stock Exchange from India), NYSE (New York Composite Index from the US), FTSE (Financial Times Stock Exchange 100 Index from the UK), HANG SENG (HSI from Hong Kong),

EURONEXT (100 Index pan Europe), SSE (Shanghai Composite Index from China) and NIKKEI (225 of Japan). We include only one index from a country wherever there is more than one index in the top ten. The World Health Organisation declared the COVID-19 pandemic on March 11, 2020. Because such an official announcement is a confirmation of the same and will affect the financial markets, we select this date as the cut-off date. Therefore, the date has been chosen exogenously in line with Boubaker et al. (2016).

The data for pre-COVID analysis encompasses the period from January 4, 2017, to March 11, 2020. The data for post-COVID analysis spans the period from March 12, 2020, to October 30, 2020. Data is obtained from Yahoo Finance. We present the summary statistics of the indices in Table 1 and Table 2 to get a preliminary understanding of the data. Table 3 and Table 4 show the correlation of the indices as expressed in logarithmic form.

3.2. Methodology

We start our analysis with the unit root test, as the presence of non-stationarity can result in spurious regression output. A time series is said to be stationary when the mean, variance, and co-variance remain constant over time. We check for stationarity using the Augmented Dickey-Fuller (ADF) test. The null hypothesis for the unit root test is that the series is non-stationary. If the value of the t-statistic is greater than the 5% critical value, the null is rejected. The test is based on the following equation:

$$\Delta Y_t = a_0 + \delta Y_{t-1} + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-2} + \ldots + \beta_p \Delta Y_{t-p} + \varepsilon_t u_t \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

To ascertain the long-run cointegration, the Johansen Cointegration test is applied. All series must be stationary in the first difference, i.e., I (1), to apply the test. An increase in the number of cointegration vectors between the pre-crisis period and the crisis period indicates the contagion effect of a crisis (Sander and Kleimeier, 2003; Boubaker et al., 2016). Johansen's multivariate cointegration test is based on the following vector auto-regression (VAR) equation:

$$Y_t = A_1 Y_{t-1} + \ldots\ldots\ldots A_p Y_{t-p} + Bx_t + u_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where yt and xt are, respectively, a k-vector of non-stationary I (1) variables and a vector of deterministic variables, and ut is a vector of innovations. We derive the following equation based on Equation 1:

$$\Delta yt = \prod y_{t-1} + \Sigma \sum_{i=1}^{p} \Gamma i \, \Delta y_{t-i} + \beta x_t + u_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\text{Where } \prod = \Sigma \sum_{i=1}^{p} Ai - I \text{ and } \Gamma i = \Sigma \sum_{j=i+1}^{p} Aj$$

According to Engle and Granger (1987), if the matrix constructed ∏ has reduced the position r <k, there are k * r matrices of α and β, each with the rank ∏ = αβ, and β'yt is I (0). For the Johansen method, we compute the ∏ matrix and test whether we can reject the limits shown at the reduced rank by ∏ using either a trace matrix statistic

or the maximal eigenvalue statistic. We also apply the Granger causality test to determine the causal relationships between the stock indices. We use the Vector Error Correction Mechanism (VECM) for determining causality, as Engle and Granger (1987) suggested when there is evidence of cointegration. The VECM also indicates the time taken for the endogenous variables to return to their equilibrium position. Selection of appropriate lag length is important, and we use the Akaike Information Criterion (AIC). Further, to understand the time effects of the shock, we also run the Impulse Response Function test.

4. Results

We present the descriptive statistics of, and correlation among, the stock indices under consideration. We also discuss the estimation results of the stationarity tests and Johansen's cointegration test. We then proceed to present causality results based on the VAR-VECM models. Finally, we compute each stock index's impulse response functions when paired with BSE-SENSEX.

4.1. Descriptive statistics

Table 1 indicates descriptive statistics for the stock returns before Covid-19. For this period, the highest mean return is seen in BSE-SENSEX, and the lowest

Table 1. Summary statistics for the Pre-COVID period

	Mean	S.D.	Skewness	Kurtosis
BSE	0.047	0.891	-0.527	9.317
EURONEXT	-0.003	0.944	-1.996	15.633
FTSE	-0.029	0.902	-1.898	14.896
HANGSENG	0.025	1.159	-0.649	6.192
NIKKEI	0.016	1.040	-0.590	5.020
NYSE	0.011	0.844	-1.122	8.876
SSE	-0.002	1.176	-0.537	9.097

Source: Authors' calculation

in FTSE. SSE is the most volatile, and NYSE is the least risky during this period. An important observation is that Euronext, FTSE, and SSE generate negative returns. The results also indicate that the skewness coefficient is negative for all the stock returns, implying a long-left tail. Kurtosis exceeds three, indicating that the distribution is leptokurtic.

Table 2 presents the statistics of the select stock markets for the post covid period. We find that, once again, the highest mean return is that of the BSE-SENSEX. However, the lowest return is that of HANG SENG. All the stock returns indicate much greater volatility during this time. NYSE is the most volatile, and SSE is the least volatile. This is exactly in reverse to the pre-Covid period. BSE-SENSEX and NYSE remain negatively skewed, while the other coefficients indicate positive skewness. Kurtosis continues to be greater than three for all the returns. The correlation coefficients between BSE-SENSEX and the other stock markets are positive during

the pre-covid period (Table 3). In the post-covid period, the correlation coefficient of BSE-SENSEX with Nikkei shows a negative relationship, while all others continue to remain positive.

The level of correlation is highest between BSE and HANG SENG in the pre-covid period and between BSE-SENSEX and EURONEXT in the post-Covid period.

Table 2. Summary statistics for the Post-COVID period

	Mean	S.D.	Skewness	Kurtosis
BSE	0.171	2.272	-0.073	6.825
EURONEXT	0.147	1.983	0.300	5.293
FTSE	0.068	1.984	0.506	5.668
HANGSENG	0.007	1.644	0.082	4.269
NIKKEI	0.117	2.065	0.725	7.326
NYSE	0.121	2.628	-0.631	8.683
SSE	0.095	1.363	0.361	6.109

Source: Authors' calculation

Table 3. Correlation Matrix for the Pre-COVID period

	BSE	EURON EXT	FTSE	HANGS ENG	NIKEI	NYSE	SSE
BSE	1.000	0.412	0.395	0.472	0.338	0.295	0.293
EURONEXT	0.412	1.000	0.853	0.475	0.377	0.417	0.330
FTSE	0.395	0.853	1.000	0.489	0.325	0.384	0.348
HANGSENG	0.472	0.475	0.489	1.000	0.550	0.438	0.659
NIKKEI	0.338	0.377	0.325	0.550	1.000	0.451	0.373
NYSE	0.295	0.417	0.384	0.438	0.451	1.000	0.330
SSE	0.293	0.330	0.348	0.659	0.373	0.330	1.000

Source: Authors' calculation

The lowest correlation is between BSE and SSE before the pandemic and between BSE-SENSEX and NYSE in the second period. Overall, the correlations are higher in the post-pandemic period, indicating an increased shock transmission among the financial markets (Table 4). The higher correlations are the first sign of greater cointegration among the markets.

Table 4. Correlation Matrix for Post-Covid period

	BSE	EURO NEXT	FTSE	HANG SENG	NIKKEI	NYSE	SSE
BSE	1.000	0.586	0.613	0.578	-0.088	0.211	0.252
EURONEXT	0.586	1.000	0.925	0.642	-0.134	-0.056	0.155
FTSE	0.613	0.925	1.000	0.578	-0.110	-0.068	0.160
HANGSENG	0.578	0.642	0.578	1.000	0.044	0.192	0.221
NIKKEI	-0.088	-0.134	-0.110	0.044	1.000	0.105	0.047
NYSE	0.211	-0.056	-0.068	0.192	0.105	1.000	0.031
SSE	0.252	0.155	0.160	0.221	0.047	0.031	1.000

Source: Authors' calculation

4.2. Cointegration Test Results

Before testing for cointegration, we check the stationarity of the time series for both the pre-and post-covid periods. We apply the ADF test on the variables at intercept as well as a linear trend. Table 5 indicates the results of the A.D.F. unit root test at the level and first difference. We find that the series are non-stationary at level but are stationary at first difference. This aligns with the behaviour of most financial data series.

Table 5. Unit root test results

Country/SE	Pre-Covid		Post-Covid	
	ADF		ADF	
	Intercept	Trend	Intercept	Trend
India (BSE)	-2.682	-2.468	-1.915	-3.885
	-24.804***	-24.916***	-5.309***	-5.710***
EURONEXT_100	-2.290	-1.754	-3.206	-1.464
	-21.534***	-21.610***	-8.311***	-8.626***
FTSE	-1.999	-2.294	-4.033	-2.095
	-4.589***	-4.725***	-9.391***	-4.806***
HANGSENG	-2.771	-2.443	-2.751	-3.043
	-11.644***	-11.802***	-11.247***	-11.204***
NIKKEI	-2.200	-2.320	-5.039	-3.077
	-17.000***	-17.002***	-5.868***	-7.249***
NYSE	-2.501	-2.368	-2.053	-3.544
	-11.372***	-11.445***	-6.415***	-6.514***
SHANGHAISE	-1.865	-2.164	-1.187	-2.364
	-7.886***	-7.880***	-9.662***	-9.624***

Source: Authors' calculation. Notes: The top value is for the level series, and the bottom value is for the first difference. ***denotes stationarity at 1%. ADF signifies the Augmented Dickey-Fuller test. The pre-Covid period is from 04/01/2017 to 11/03/2020. The post-Covid period is from 12/03/2020 to 30/10/2020

Table 6. Cointegration results–Pre-Covid among markets (period- January 2017 – 11 March 2020)

Null hypothesis	Trace	5% Critical value	Max. eigenvalue	5% Critical value
r=0	126.868*	125.615	43.865	46.231
r≤1	83.004	95.754	37.581	40.078
r≤2	45.423	69.819	17.921	33.877
r≤3	27.503	47.856	10.993	27.584
r≤4	16.510	29.797	7.438	21.132
r≤5	9.072	15.495	5.024	14.265
r≤6	4.048	3.841	4.048	3.841

Source: Authors' calculation. Notes: r denotes the number of cointegration relationships to be tested. ***, ** and * denote rejection of the null hypothesis at 1%, 5% and 10% levels, respectively.

There is evidence of long-run cointegration among the select stock indices, for both the pre-Covid and post-Covid series, as per both the Trace and the Maximum Eigen Values. The Trace statistics test indicates one cointegrating equation among the seven stock markets in the pre-Covid period. This statistic shows a long-run relationship between the BSE-SENSEX and NYSE, EURONEXT, FTSE, NIKKEI, HANG SENG, and SSE.

Table 7. Cointegration results – Post-Covid among markets (period- 12 March 2020 – October 2020)

Null hypothesis	Trace	5% Critical value	Max. eigenvalue	5% Critical value
r=0	153.302*	125.615	57.069*	46.231
r≤1	96.233*	95.754	31.143	40.078
r≤2	65.090	69.819	29.013	33.877
r≤3	36.077	47.856	15.652	27.584
r≤4	20.425	29.797	11.295	21.132
r≤5	9.130	15.495	5.260	14.265
r≤6	3.871	3.841	3.871	3.841

Source: Authors' calculation. Notes: r denotes the number of cointegration relationships to be tested. ***, ** and * denote rejection of the null hypothesis at 1%, 5% and 10% levels, respectively.

In the post-Covid period, there are two cointegration equations of the Trace statistic and one of the Max-eigenvalue at a 5% critical level. The increased number of cointegrating equations, post-Covid-19, supports our argument that the markets are cointegrated at a higher level post the pandemic. Our finding of increased cointegration is in line with similar comparative studies which examine the impact of the 2008 financial crisis on the stock markets. In their study, Gulzar et al. (2019) reported increased cointegration in the post-financial crisis period. Boubaker et al. (2016) also found that there is greater cointegration in the turbulent period (post-crisis) as compared to the tranquil period (pre-crisis).

Having established that the markets are cointegrated, it becomes important to study the short-run and long-run causal linkages by examining the Granger causality using the VEC mechanism.

4.3. VAR-VECM Models

We run the VEC Block Exogeneity Wald Tests to examine the short-run causal effects.

Pre-covid period: The results of the pre-Covid period indicate a short-run causal linkage from the NIKKEI to the BSE. In turn, the BSE granger causes the HANG SENG and the FTSE. There is scope for cross-investments between BSE-SENSEX and NYSE, EURONEXT, and SSE.

As far as NYSE is concerned, there are short-run interlinkages from EURONEXT & SSE & HANG SENG to NYSE. Although there is a long-run cointegration between NYSE and the other stock exchanges, NYSE does not granger cause any of the other stock

exchanges under study. Overall, there is scope for cross-investments between NYSE and FTSE, NIKKEI, and BSE.

There are also possibilities for cross-investments between FTSE and EURONEXT, NIKKEI, HANG SENG, and SSE. Similarly, since there are no short-run linkages between EURONEXT and SSE, NIKKEI and HANG SENG, and SSE and HANG SENG, there is scope for investments across these markets.

Post-covid period: The VEC Block Exogeneity Wald Test results show a short-run causal linkage from the BSE-SENSEX to the NIKKEI, FTSE, and EURONEXT. In addition, the NYSE granger causes BSE-SENSEX. Our findings align with Wong et al. (2005), who find causality between India and the mature markets. The other markets under study, i.e., HANG SENG and SSE, can benefit from short-term investments in BSE and vice versa. There is no short-run linkage between them. There is a bi-directional relationship between NYSE and NIKKEI. NYSE also granger causes FTSE, EURONEXT, and BSE-SENSEX. There is scope for diversification from the US to the financial markets of Hongkong and China and vice versa.

FTSE and EURONEXT have a bi-directional causality. Further, there is unidirectional causality from NYSE and BSE-SENSEX to both these financial markets. Considering these short-run linkages, the possibility for diversification lies in NIKKEI for investors from the UK and vice-versa. As far as the South-East Asian markets are concerned, HANG SENG and SSE have short-run bi-directional linkages. However, there is scope for NIKKEI and HANG SENG for cross-investments.

4.3.1. Impulse Response Functions

We examine the impulse response functions to understand the spillover effect of innovations across the equity markets. Impulse response helps measure the effect of one standard deviation of shock arising in a particular stock market on other stock markets and the time taken for equilibrium to be restored after the shock.

The responses of the various stock markets are diverse. For the pre-covid period, we find that the responses of all stock indices towards the shock of BSE-SENSEX are negative, except for NYSE. Most of the stocks return to their mean values after the fourth period. Post the covid crisis, one standard deviation of shock in BSE-SENSEX causes a greater innovation in FTSE and EURONEXT. On the other hand, NIKKEI shows a negative impact followed by stabilizing in the positive area after the third period and then reverting to the mean. NYSE reacts positively to the shock in the BSE and then reverts to zero. There are definite signs of greater volatility in the graphs of the stock markets in response to shocks in the aftermath of covid. All the financial markets, except HANG SENG and NIKKEI, also react negatively to the shock arising from NYSE. This is in line with some of the earlier studies, such as by Gulzar et al. (2019).

4.3.2. Comparative analysis between pre-COVID and post-COVID

We now compare the results of the Johansen Co-Integration test, VECM, and Impulse response function to understand the impact of the Covid pandemic on the cointegration of stock markets. We find one cointegrating equation among the seven stock markets for the pre-Covid period. We find that there are two cointegration equations in the post-Covid period. This implies that the markets are cointegrated at a higher order post-pandemic.

Our VEC-Granger Causality test results indicate that in the pre-covid period, there were only a few inter-linkages in the short run among the stock exchanges, leaving scope for short-term gains by proper portfolio diversification. We find a greater number of short-run linkages post the pandemic, strongly demonstrating a transmission effect. There is less chance of short-term gains after such an event due to the contagion effect.

5. Conclusion

Stock markets across the globe reacted strongly to the pandemic situation. Our research focuses on the transmission of the pandemic shock across major stock market indices globally and with special reference to India. We use cointegration techniques and Vector Error Correction Mechanism to understand the nature of long- and short-run cointegration. We also apply the impulse response function to measure market returns' direction and response time to innovation in their own and the other indices.

For our study, the Johansen cointegration test is an indicator of the contagion effects if the number of cointegrating vectors is higher post-Covid-19. The results of the Johansen cointegration test for the pre-Covid period indicate one cointegrating equation, and in the post-Covid period, a higher number of long-run cointegrating equations among the BSE and other six stock markets. This implies that the markets are cointegrated at a higher order post-pandemic. The reason for long-run cointegration among the chosen markets could be because there are greater inter-dependencies among the economies, higher levels of trade, and also investments in terms of FDIs and FIIS.

We then apply the VEC Block Exogeneity Wald Tests to examine the short-run causal effects. Our results indicate that in the pre-COVID time, there were linkages between the stock markets of India and the U.K., Japan, and Hongkong. There is unidirectional causality from the UK to India, while the Indian stock market leads the two Asian indices. However, the post-pandemic results indicate the shock transmission effects from India to two very important European indices, i.e., the U.K. and Euronext stock exchanges and Japan’s stock market. We also see transmission effects from the US to India post-Covid period. A possible reason for such linkages could be the cross-holdings in stocks across these countries. We find evidence that there are greater linkages post the pandemic.

We also observe significant changes in the causal relationships among the indices and in the direction of the causality. The increased inter-linkages make portfolio diversification a challenge. In the pre-covid period, causality was absent between India and the US, Europe, and China, providing scope for diversification. In sharp contrast, post the pandemic, India does not have short-run linkages only with the stock markets of Hongkong and China. Overall, we conclude that there is evidence in our data to suggest both long-run and short-run cointegration among the stock markets, to a greater extent, in the post-pandemic period.

Our study contributes in the following ways. We examine the impact of the COVID-19 pandemic on the interlinkages between the Indian stock market and some of the largest indices across the world. We compare these stock markets' pre-covid and post-covid cointegration to identify the possibilities for international portfolio diversification. Portfolio investors can then decide their portfolio reallocation to maximize returns and minimize the risk arising from such events. The study can be further extended by including a larger number of stock markets and examining the volatility arising from this pandemic.

References

Ashraf, B. N. (2020). Stock markets' reaction to COVID-19: Cases or fatalities?. *Research in International Business and Finance,* 54, 101249.https://doi.org/10.1016/j.ribaf.2020.101249

Baele, L., & Inghelbrecht, K. (2009). Time-varying integration and international diversification strategies. *Journal of Empirical Finance,* 16(3), 368-387 https://doi.org/10.1016/j.jempfin.2008.11.001

Bhattacharya, K. and Samanta, G.P. (2001). A tale of two indices: the story of the NASDAQ and the Sensex. Journal of Quantitative Economics, 1, 89-102. https://doi.org/10.1007/BF03404651

Bhunia, A., & Ganguly, S. (2020). An assessment of volatility and leverage effect before and during the period of Covid-19: a study of selected international stock markets. *International Journal of Financial Services Management,* 10(2), 113-127. https://doi.org/10.1504/IJFSM.2020.110224

Bhuyan, R., Lin, E. C., & Ricci, P. F. (2010). Asian stock markets and the severe acute respiratory syndrome (SARS) epidemic: Implications for health risk management*. International Journal of Environment and Health,* 4(1), 40-56. https://doi.org/10.1504/IJENVH.2010.033033

Boubaker, S., Jouini, J., & Lahiani, A. (2016). Financial contagion between the US and selected developed and emerging countries: The case of the subprime crisis. *The Quarterly Review of Economics and Finance,* 61, 14-28. https://doi.org/10.1016/j.qref.2015.11.001

Chakrabarti, P., Jawed, M. S., & Sarkhel, M. (2021). COVID-19 pandemic and global financial market interlinkages: a dynamic temporal network analysis*. Applied Economics*, 53(25), 2930-2945. https://doi.org/10.1080/00036846.2020.1870654

Chen, H., Lobo, B. J., & Wong, W. K. (2006). *Links between the Indian, US and Chinese stock markets.* National University of Singapore, Department of Economics, Working Paper, 602.

Chen, N. F., Roll, R., & Ross, S. A. (1986). Economic forces and the stock market. *Journal of Business*, 383-403. https://doi.org/10.1086/296344

Driessen, J. and Laeven, L. (2007). International portfolio diversification benefits: Cross-country evidence from a local perspective. *Journal of Banking & Finance,* 31(6), 1693-1712. https://doi.org/10.1016/j.jbankfin.2006.11.006

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 251-276. https://doi.org/10.2307/1913236

Forbes, K. J., & Rigobon, R. (2002). No contagion, only interdependence: measuring stock market comovements. *The Journal of Finance*, 57(5), 2223-2261. https://doi.org/10.1111/0022-1082.00494

Granger, C. W. J., & Morgenstern, O. (1970). *Predictability of Stock Market Prices*. Lexington, MA: Heath Lexington Books.

Grubel, H.G. (1968). Internationally diversified portfolios: welfare gains and capital flows. *American Economic Review*, 58(5), 1299-1314.

Gulzar, S., Mujtaba Kayani, G., Xiaofen, H., Ayub, U. and Rafique, A., (2019). Financial cointegration and spillover effect of global financial crisis: A study of emerging Asian financial markets. *Economic research-Ekonomska istraživanja,* 32(1), 187-218. https://doi.org/10.1080/1331677X.2018.1550001

Gupta, H., Chaudhary, R. & Gupta, S. (2021). COVID-19 impact on major stock markets. *FIIB Business Review,* 2319714521994514 https://doi.org/10.1177/2319714521994514

Habiba, U. E., Peilong, S., Hamid, K., & Shahzad, F. (2021). Stock returns and asymmetric volatility spillover dynamics between Asian emerging markets. *Global Business Review,* 22(5), 1131-1145. https://doi.org/10.1177/0972150919838433

Jelilov, G., Iorember, P.T., Usman, O. & Yua, P.M., (2020). Testing the nexus between stock market returns and inflation in Nigeria: Does the effect of COVID-19 pandemic matter? *Journal of Public Affairs*, 20(4), e2289. https://doi.org/10.1002/pa.2289

Jeon, B.N. and von Frustenberg, G.M. (1990). Growing international comovement in stock indexes. *Quarterly Review of Economics and Finance*, 30(30), 17-30.

Kasa, K. (1992). Common stochastic trends in international stock markets. *Journal of Monetary Economics*, 29, 95-124. https://doi.org/10.1016/0304-3932(92)90025-W

Keogh-Brown, M.R. and Smith, R.D., (2008). The economic impact of SARS: how does the reality match the predictions?. *Health Policy,* 88(1), 110-120. https://doi.org/10.1016/j.healthpol.2008.03.003

Levy, H. and Sarnat, M., (1970). Diversification, portfolio analysis and the uneasy case for conglomerate mergers. *The Journal of Finance,* 25(4), 795-802. https://doi.org/10.1111/j.1540-6261.1970.tb00553.x

Liu, H., Manzoor, A., Wang, C., Zhang, L., & Manzoor, Z. (2020). The COVID-19 outbreak and affected countries stock markets response. *International Journal of Environmental Research and Public Health,* 17(8), 2800. https://doi.org/10.3390/ijerph17082800

Mahajan, S., & Mahajan, P. (2021). Impact of COVID-19 on Stock Market and Gold Returns in India. *Eurasian Journal of Business and Economics,* 14(27), 29-46 https://doi.org/10.17015/ejbe.2021.027.02

Markowitz, H. (1952). The utility of wealth. *Journal of Political Economy,* 60(2), 151-158. https://doi.org/10.1086/257177

Peckham, R. (2013). Economies of contagion: financial crisis and pandemic. *Economy and Society,* 42(2), 226-248. https://doi.org/10.1080/03085147.2012.718626

Rajwani, S and Mukherjee, J. (2013). Is the Indian stock market cointegrated with other Asian markets?. *Management Research Review*, 36 (9), 899-918. https://doi.org/10.1108/MRR-06-2012-0141

Ramelli, S. and Wagner, A. F. (2020). Feverish stock price reactions to COVID-19. *The Review of Corporate Finance Studies*, 9(3), 622-655. https://doi.org/10.1093/rcfs/cfaa012

Ripley, D.M. (1973). Systematic elements in the linkage of national stock market indices. *Review of Economics and Statistics,* 55(3), 356-361. https://doi.org/10.2307/1927959

Saha, M. and Bhunia, A. (2012). Financial market integration of South Asian countries. *Developing Country Studies*, 2(1), 45-52.

Sander, H., & Kleimeier, S. (2003). Contagion and causality: an empirical investigation of four Asian crisis episodes. *Journal of International Financial Markets, Institutions and Money,* 13(2), 171-186. https://doi.org/10.1016/S1042-4431(02)00043-4

Senol, Z., & Zeren, F. (2020). Coronavirus (COVID-19) and stock markets: The effects of the pandemic on the global economy. *Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi*, 7(4), 1-16

Siu, A., & Wong, Y. R. (2004). Economic impact of SARS: the case of Hong Kong. *Asian Economic Papers,* 3(1), 62-83. https://doi.org/10.1162/1535351041747996

Solnik, B. H. (1974). Why not diversify internationally rather than domestically? *Financial Analysts Journal*, 30(4), 48-54. https://doi.org/10.2469/faj.v30.n4.48

Srivastava, A. (2007). "Cointegration of Asian markets with US markets: international diversification perspectives. *Global Business Review,* 12 (3), 251-265. https://doi.org/10.1177/097215090700800205

Tripathi, V. and Sethi, S. (2010). Integration of Indian stock market with major global stock markets. *Asian Journal of Business and Accounting,* 3(1), 117-134.

Wong, W. K., Agarwal, A., & Du, J. (2005). *Financial integration for India stock market, a fractional cointegration approach*. National University of Singapore Working Paper No. WP0501

Wren-Lewis, S. (2020). The economic effects of a pandemic. In Baldwin, R. & Weder di Mauro, B. (Eds), *Economics in the Time of COVID-19,* (pp. 109-112.). London: CEPR Press

Yarovaya, L., Brzeszczynski, J., Goodell, J. W., Lucey, B. M., & Lau, C. K. (2020). *Rethinking Financial Contagion: Information Transmission Mechanism During the COVID-19 Pandemic*. Available at SSRN 3602973. https://doi.org/10.2139/ssrn.3602973

Zeren, F., & Hizarci, A. (2020). The impact of COVID-19 coronavirus on stock markets: evidence from selected countries. *Muhasebe ve Finans İncelemeleri Dergisi,* 3(1), 78-84. https://doi.org/10.32951/mufider.706159