The Nexus of Stock Markets Among BRICS Nations : An Empirical Analysis Pre and Post Spread of the COVID-19 Pandemic

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Abstract

The present corroborations from the empirical literature on the interconnections of BRICS stock markets have been conflicted. Thus, the present paper attempted to re-examine both the long and short-run nexus among BRICS stock markets before and after the COVID-19 pandemic. The current study period was segregated into two sub-periods to compare long and short-run dynamics among BRICS stock indices pre and through the times of distress and the exorbitant volatility caused by the COVID-19 pandemic. It used daily closing values of the BRICS stock market indices from January 1, 2010 to November 30, 2019 as the pre-spread COVID-19 pandemic phase and from December 1, 2019 to April 30, 2021, the post-spread COVID-19 pandemic phase. Furthermore, this study undertook the Johansen cointegration test, vector error correction model (VECM), and the Granger causality tests to examine the long and short-term nexus of the BRICS stock indices. The study findings suggested that BRICS stock markets shared linkages in totally different manners pre- and post-spread of the COVID-19 pandemic. The study findings will benefit institutional investors, individual investors, high net worth individuals, and public investors for finalizing their investment and hedging strategies for availing the opportunities of diversifying investment risk and earning high returns due to existing relations among the BRICS stock markets.

Keywords : **BRICS economies, cointegration, covariance, Granger causality, VECM**

JEL Classification Codes : F21, F29, G11, G15, G18, N20

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World economies' financial and economic systems have increasingly become integrated, as reasoned by the swift growth of international trade in financial and commodity markets across the globe. On the one side, the economic integration of various countries is growing due to a tremendous jump in the volumes of imports and exports of goods. On the other side, the integration of financial markets is also rising even at a higher velocity resulting from liberalization of capital markets and ease of capital flow movement because of much more leveraged and relaxed capital controls among economies.

The presence of cointegration among different nations' financial markets suggests lower diversification benefits. On the other hand, the absence of cointegration among stock markets provides diversification benefits to investors. Thus, international diversification assists the investors in improving the risk-reward ratio and decreasing unsystematic risk, that is, country-specific risk. However, such benefits fade out in the presence of cointegration among financial markets. In such a situation, the investors attempt to look for the best portfolios in terms of risk and return equilibrium in integrated international financial markets with lots of rigorous efforts. Even

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the cointegration of financial markets among economies remarkably affects the potentiality of their respective regulatory bodies to formulate independent economic policies.

Majorly BRICS countries are extremely affiliated economies in their corresponding regions. It is the reason behind their crucial role in the world economic dynamics relative to other world's emerging economies. Moreover, the contribution of BRICS economies to world economic dynamics implies that the concurrent economic progress or slowdown in BRICS economies will impact virtually the economic behavior of other economies and the global economy. Thus, the short-term integration and the long-term interconnections among the BRICS security markets have gained significant importance among stock market players, investors, brokers, regulators, policymakers, researchers, and academicians.

Rapidly growing financial integration among world economies makes it further essential to study and understand the linkages and associations between certain world economies by various stakeholders, specifically cross-border stock market investors, to earn higher returns on their portfolios through effective and timely hedging and diversification strategies. Thus, the major emerging world economies, especially BRICS, are drawing the attention of international institutional and individual investors as the most preferred investment destination for the ongoing decade and beyond.

The association of stock markets is equivalent to the measure of cointegration among them in financial literature. Thus, the need to comprehend the inception of such interdependence of stock markets generates from its implications on trade and monetary policies, capital requirements, resource allocation, international trade, and risk hedging. The cointegration or interdependence of stock indices of different countries has been the area of study for many economics and finance researchers since the 1970s. Many researchers have examined the short-run and long-run nexus and co-movements of Indian security, currency, and commodity market indices with other economies' market indices, including the USA, UK, European, and BRICS for different periods, such as Aggarwal and Raja (2019), Konradsson and Porss (2019), Pereira (2018), Dasgupta (2017), Mohammad Irshad and Palaniappan Shanmugam (2017), Jegadeeshwaran and Sangeetha (2018), Patel (2017), Prakash et al. (2017), Singh and Singh (2016), Vohra (2016), Tripathy (2015), Babu and Srinivasan (2014), and Chakrabarty and Ghosh (2011). However, meager research has been undertaken to showcase the nexus of BRICS stock markets for the last decade covering the COVID-19 pandemic.

Thus, the present study aims to fill up the identified research gap by examining the presence of cointegration between BRICS economies' financial markets in the last 11.4 years. It also compares the cointegration of BRICS economies' financial markets pre and post-spread of the COVID-19 pandemic worldwide. The study's findings will help individual and institutional investors strategize their investment decisions to gain the best returns if they are interested in investing in any of the BRICS economies. In addition, the results of the study will also contribute to the literature related to financial markets. The current research will append to the present literature on how the research area on the interdependence of stock markets has evolved, focusing on its cause and effect on market integration and highlighting the scope for further research in this area. The present study results will benefit policymakers and regulatory bodies of BRICS nations when making economic and financial market policies.

Review of Literature

Globalization has interconnected worldwide countries and their markets and made them interdependent. Undoubtedly, many factors affect the financial market movements, and cointegration is one of them. The cointegration of financial markets is most apparent nowadays. This incorporates both long and short-term linkages. Individual and institutional investors, brokers, and other financial market players strategize their investments by considering the integration of financial markets.

Several studies investigated the interrelation of various countries' stock, currency, and commodity markets for

different time horizons and other indices. Many researchers have investigated such integration of stock markets pre, post, and during various financial and economic crises such as the subprime crisis, the Asian crisis, and the global financial crises. The COVID-19 pandemic is the most recent global crisis. Along with market integrations, many researchers have examined linkages of various economic indicators of different nations. Recent studies showed the inclination of researchers toward integrations of markets and their economic indicators of BRICS economies. Aderemi et al. (2019) observed the association between economic growth and FDIs (foreign direct investments) in BRICS countries. The study showed that economic growth and FDIs shared a long-run equilibrium association. Unidirectional causality running from FDIs to economic growth was also found during the study period. Gupta et al. (2016) found that economic growth caused ADR returns positively in the long-run in the Chinese and Brazilian markets. However, ADR returns were found to be negatively driven by the economic development in the Russian and Indian markets. The study further revealed that ADR prices drove Brazil's oil prices and inflation rates. Furthermore, oil prices predicted ADR returns in Russia. Siddiqui and Qurashi (2015) examined the impact of the formation of the BRIC group on its stock market movements. The researchers indicated that the formation of the BRIC barely impacted long-term integration and casual relationship among the financial markets of BRIC economies. This is how the researchers examined the linkages of economic indicators of BRICS or BRIC economies for assisting the financial system stakeholders.

Many researchers have studied the nexus of BRICS financial markets to explore diversification opportunities for investors in these economies' financial markets. Aggarwal and Raja (2019) studied the cointegration among the BRIC nations' stock markets to examine their co-movement in the long run. At least one long-term cointegrating association among the considered four security markets was confirmed to have existed under study. Konradsson and Porss (2019) examined the existence of long-term diversification opportunities presented for international investors in BRICS economies during 1999 – 2019. The results suggested that the BRICS stock markets had constant risk-premium and equivalent systematic risk factors. Moreover, the findings also indicated the existence of various causal associations between the BRICS economies with China as the primary leading economy.

Ben Nasr et al. (2018) suggested that all BRICS nations are not similar in how these markets respond to rating changes and interact with global market variables. Raja (2018) confirmed that from January 1, 2000 to November 30, 2013, the Chinese and Indian currency markets were integrated, implying that these two markets did not provide diversification benefits in the long term. However, Brazil and Russia's stock markets provided more excellent diversification benefits due to the absence of cointegration. Prakash et al. (2017) proved that weak long-term cointegration existed among BRICS' equity markets. Singh and Singh (2016) reported that market behaviour changed across the period and that the BRICS markets shared partial integration from 2004 – 2014. Joshi (2013) examined the association between indices of BRIC economies from 2002 – 2012 through Granger causality and correlation analysis. Indian security market was confirmed to correlate positively with the Chinese and Russian stock markets. The Indian stock market was further found to share long-run relations with China and Russia, implying investors had no diversification opportunities in these three countries. It was also observed that the Indian security market did not share any long-term association with the Brazilian security market; thus, it gave investors diversification opportunities.

Along with BRICS, many researchers have examined the co-movement of other economies to assist cross-border investors in formulating better hedging strategies. Nautiyal and Kavidayal (2018) established the presence of short-term causality running from the Hong Kong security market to the Indian security market and from the financial markets of France to China, India to Malaysia, and Germany to Korea. The study further revealed the existence of long and short-term linkage among the chosen countries, that is, five rising benchmark economies (India, China, Korea, Russia, and Malaysia) and six developed benchmark economies (USA, UK, Japan, France, Hong Kong, and Germany). Pereira (2018) indicated that variations in the Eurozone and USA stock market

indices influenced the BRICS stock markets in the short term. It was further concluded that these two major countries' stock markets behaved as a driving force for investing in the BRICS stock markets. Patel (2017) examined the co-movement between 14 stock markets, that is, TSEC, SSE, SSMI, NASDAQ, NIKKKI, KSE (Korea), RTS, KSE, JKSE, Hang Seng, FTSE-100, BVSP, MXX, and BSE from January 1, 1998, to January 31, 2017. A positive correlation was found between BSE and other countries' stock markets, namely Hang Seng, FRSE-100, NASDAQ, SVSP, MXX, and BVSP. Unidirectional Granger causality was directed from BVSP, MXX, and FTSE-100 to BSE returns. Long-run relation was confirmed to exist among the chosen stock markets through the Johansen cointegration test.

Bhattacharjee and Swaminathan (2016) concluded that the Indian stock markets were cointegrated with the stock markets of selected countries under study. It was also observed that such cointegration had been improving post-liberalization in India. The Indian security market was established as more responsive to other Asian stock markets during the recession. Singh and Singh (2016) observed the financial association between BRIC and US economies from 2004 – 2014. Mitra and Bhattacharjee (2015) extensively surveyed the present literature on cointegration among the international stock markets. The researchers also reviewed prospective and present-day methodologies to identify cointegration and evaluate the level of such linkages among global stock markets. Chakrabarty and Ghosh (2011) confirmed the presence of cointegration between the USA and UK stock markets. It was also established that these two developed economies' financial markets affected the Indian financial market in the long term. Thus, it was concluded that it would not be fruitful for Indian investors to invest in US and UK stock markets for hedging due to such long-run cointegration among these markets.

Talking about other economies, many researchers support the existence of cointegration among stock markets of selected countries, as aforementioned. Many researchers have also studied the cointegration of different indices and economic indicators of individual country stock, commodity, and currency markets. Vohra (2016) assessed the mutual associations and performance of different indices of the Bombay Stock Exchange from April 1, 2008 to March 31, 2014. Various stock indices of the Bombay Stock Exchange were found to share causal relations and cointegration among them. Babu and Srinivasan (2014) analyzed the association between future and spot prices in the commodity markets of India starting from January 1, 2012 and ending December 31, 2012, by selecting 10 commodities based on their turnover. It was found that future prices did not influence the spot prices of the considered sample commodities.

As mentioned above, much-existing literature corroborates the presence of short or long-run cointegration among stock markets, commodity markets, currency markets, or economic indicators of globalized economies. However, many researchers have concluded contradictory results in terms of the absence of any integration in the stock markets of BRICS economies. Mohammad Irshad and Palaniappan Shanmugam (2017) concluded that there was no long-term relationship among BRICS economies between 2005 – 2015. However, a few unidirectional cause and effect relationships existed during the study period. Ouattara (2017) confirmed the absence of long-run cointegration between the BRICS financial markets from 2000 – 2015. Hence, the results suggested that BRICS stock markets might prove favorable and profitable destinations for long-term investments and hedging purposes. Verma and Rani (2015) investigated the linkage among short-term causal associations among BRIC market indices from 2010 – 2014. No long-run connections were found among the BRIC stock indices. The findings further concluded that only the Brazilian stock market had unidirectional causality with the Indian stock market.

When we talk about the presence of causality among interconnected and interdependent worldwide stock markets, again, existing literature gives contradictory views. Dasgupta (2017) found that Chinese security markets' movements caused variations in the Brazilian security market, and the Brazilian security market caused variations in the Russian security market. It was further assessed that the Indian stock market had a high and firm impact on the Russian and Brazilian stock markets. Jegadeeshwaran and Sangeetha (2018) established the

unidirectional relationship between IBOVESPA & RTSI and ALSI & JSE. The study's findings recommended that the investors could reap the diversification benefits of their portfolio investments in other BRICS countries. Tripathy (2015) established a bidirectional causal association between the "Russian and Indian" and "Russian and Brazilian" security markets. It was further concluded that the Chinese security market is operating autonomously. The Chinese stock index does not share any causal relation with the Brazilian, Russian, and Indian security markets.

Researchers like Dasgupta (2017), Jegadeeshwaran and Sangeetha (2018), and Tripathy (2015) supported the presence of unidirectional or bidirectional causality among the selected indices. On another side, Prakash et al. (2017) proved an absence of any causal association between market twins like South Africa – Brazil, Russia – Brazil, China – Brazil, Russia–China, and South Africa–India.

The existing literature is somewhat inconsistent about the cointegration and causality between BRICS stock markets, and meager research is done to examine the cointegration between BRICS stock markets post spread of the COVID-19 pandemic. Thus, the present study is undertaken to fill up the identified research gap. It aims to compare the cointegration of BRICS stock markets before and after the spread of the COVID-19 pandemic.

Research Aims and Methodology

The present study intends to reveal the recent nexus shared by the BRICS stock markets to fill the identified research gap. It also aims to compare the existence of cointegration and causal association between financial markets of BRICS nations during pre-and post-spread of the COVID-19 pandemic. It is attempting to ascertain whether there is any change in financial markets' integration of BRICS nations pre-and post-spread of the COVID-19 pandemic or not. Thus, a 10 years (approx.) period starting from January 1, 2010, and ending November 30, 2019, is taken as a pre-spread COVID-19 pandemic period. China reported its first COVID-19 case in December 2019 for the first time. So, the exceptional period of the COVID-19 pandemic, starting from December 1, 2019, and ending on April 30, 2021, is analyzed separately as the post-spread COVID-19 pandemic period.

The daily closing value of indices of BRICS economies, that is, BOVESPA of Brazil, MOEX of Russia, S&P BSE SENSEX of India, Shanghai of China, and South Africa Top 40 of South Africa were taken from the Yahoo finance website for the period of January 1, 2010 – April 30, 2021. Johansen cointegration test, VECM, and Granger causality test were used to analyze the data separately for both sub-periods of the study. The considered techniques are employed by various researchers (Bhattacharjee & Swaminathan, 2016; Chakrabarty & Ghosh, 2011; Gupta et al., 2016; Mitra & Bhattacharjee, 2015; Nautiyal & Kavidayal, 2018; Patel, 2017; Siddiqui & Qurashi, 2015; Vohra, 2016) for similar kind of studies undertaken on either different countries' financial markets or periods that corroborate the validity of the identified research methodology.

Unit root tests are undertaken to assess the integration order for individual indices. The covariance analysis determines positive or negative correlations and covariance between BRICS stock markets. The Johansen cointegration test is employed for examining the present linkages among the five emerging Asian stock markets. The vector error correction model (VECM) is applied to determine the co-movement of a long-run equilibrium nexus betwixt the selected five stock indices. The Granger causality test is further employed to evaluate causal relations among these five markets. China is the most economically stable and robust economy, followed by India relative to other BRICS nations. So, the present study focuses on checking whether any causality is being contributed to the Chinese financial markets by other BRICS nations' financial markets. EViews 11 is used to undertake the econometric techniques described above for data analysis.

The study results will mark out the nature of the integration of the selected security market indices throughout the study period by quantitative data analysis. Thus, the present research follows a descriptive design.

Hypotheses Development

The following seven hypotheses are tested to study the cointegration and causal association between the Indian stock markets and the four markets during the pre and post-spread COVID-19 pandemic period. Ha2, Ha5, Ha6, and Ha7 are the primary hypotheses to attain the research aims. However, Ha1, Ha3, and Ha4 are secondary.

- **Ha1 :** Selected data series is stationary.
- **Ha2 :** At least one significant cointegration is present in selected indices of BRICS nations in the pre-spread COVID-19 pandemic period.
- **Ha3 :** A significant serial correlation is present in the residuals.
- **Ha4 :** Heteroscedasticity is present in the residuals.
- **Ha5 :** At least one significant cointegration is present in the selected indices of BRICS nations in the post-spread COVID-19 pandemic period.
- **Ha6 :** Significant causal association exists among the selected indices pairs of BRICS nations in the pre-spread COVID-19 pandemic period.
- **Ha7 :** Significant causal association exists among the selected indices pairs of BRICS nations in the post-spread COVID-19 pandemic period.

Analysis and Results

Figure 1 depicts some integration among the financial markets of Russia, India, China, and South Africa. However, the Brazilian security market shows deviations in its movement relative to other Asian markets considered under the study from 2010 to 2019, that is, the pre-spread COVID-19 pandemic period. Therefore, let's confirm the presence of any integration among markets of BRICS nations through econometrics measures ahead.

Figure 1. ***Closing Values of BRICS Indices During the Pre-Spread COVID-19 Pandemic Period***

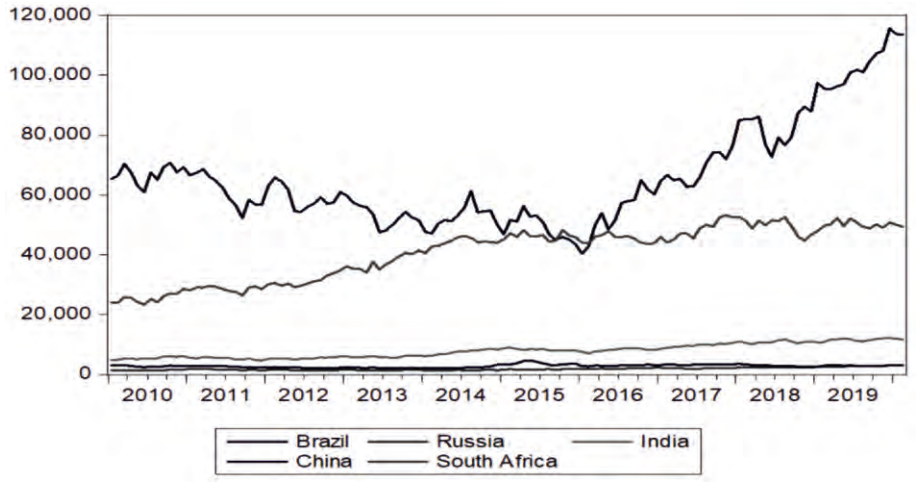

Table 1. ***Covariance and Correlation Analysis Among BRICS Indices (Pre-Spread COVID-19 Pandemic Period)***

Covariance Correlation	China	Brazil	India	Russia	South Africa
China	262387.4				
	1.000000				
Brazil	1681681.	2.96E+08			
	0.190904	1.000000			
India	575058.1	26840595	5195069.		
	0.492543	**0.684763**	1.000000		
Russia	95539.77	6663866.	925914.7	208987.2	
	0.407993	**0.847638**	**0.888619**	1.000000	
South Africa	2028512.	53140740	18208599	2790458.	80875480
	0.440350	**0.343608**	**0.888326**	**0.678746**	1.000000

The covariance and correlation analysis presented in Table 1 confirms the presence of a positive correlation betwixt the stock market pairs of BRICS nations during the pre-spread COVID-19 pandemic period.

VECM by Taking the Shanghai Index (China's Index) as the Target Variable

Augmented Dickey – Fuller Unit Root Test

As per statistics presented in Table 2, all selected variables' daily data series are observed to be stationary at $I(1)$ for the underlying period of the study, as H01 is rejected for indices at $I(1)$ at a 5% significance level. So, it is appropriate to proceed with the next steps for applying the VECM.

Table 2. ***ADF Unit Root Test Statistics***

H01 : Selected data series is non-stationary.

Ha1 : Selected data series is stationary.

Period	Index of BRICS	Original Series			Adjusted Series (Variable in First Difference)		
		t-Statistic	Probability	Result	*t*-Statistic	Probability	Result
Dec 1, 2019 –	Brazil	–1.320458	0.6210	Non-Stationary	–10.97400	0.0000	Stationary
April 30, 2021	Russia	–0.731666	0.8359	Non-Stationary	–17.63676	0.0000	Stationary
(Post-spread	India	–0.533266	0.8814	Non-Stationary	–19.58642	0.0000	Stationary
COVID-19	China	–1.460786	0.5524	Non-Stationary	–17.81026	0.0000	Stationary
pandemic period)	South Africa	–0.958166	0.7687	Non-Stationary	–18.51500	0.0000	Stationary
Jan 1, 2010 –	Brazil	–0.13073	0.9426	Non-Stationary	–10.33855	0.0000	Stationary
Nov 30, 2019	Russia	–0.138455	0.9417	Non-Stationary	–9.815994	0.0000	Stationary
(Pre-spread	India	–0.804120	0.8141	Non-Stationary	–10.33758	0.0000	Stationary
COVID-19	China	–1.883938	0.3389	Non-Stationary	–9.326266	0.0000	Stationary
pandemic period)	South Africa	–2.075822	0.2548	Non-Stationary	–13.93748	0.0000	Stationary

Optimum Lag Pick Criteria

By looking at the results of the VAR lag order presented in Table 3, lag 2 is selected as per the Akaike information criterion for the further steps to apply VECM for the pre-spread COVID-19 pandemic period.

By looking at the results of the VAR lag order presented in Table 4, lag 3 is selected for the further steps to apply VECM as per the Akaike information criterion for the post-spread COVID-19 pandemic period.

Johansen Cointegration Test (Pre-Spread COVID-19 Pandemic Period)

↳ **H02 :** No significant cointegration is present in the selected indices of BRICS nations in the pre-spread COVID-19 pandemic period.

↳ **Ha2 :** At least one significant cointegration is present in the selected indices of BRICS nations in the pre-spread COVID-19 pandemic period.

Table 3. ***Test Statistics (VAR Lag Order) (Pre-Spread COVID-19 Pandemic Period)***

Lag	LogL	LR	FPE	AIC	SC	HQ
0	350.6333	NA	1.60e–09	–6.063734	–5.943734	–6.015038
1	1015.442	1259.638	2.14e–14	–17.28846	–16.56841	–16.99623
2	1035.092	35.50756	2.35e–14*	–17.19460*	–15.87450*	–16.65885*
3	1058.915	40.95892	2.42e–14	–17.17395	–15.25381	–16.39467
4	1071.908	21.19829	3.02e–14	–16.96329	–14.44311	–15.94049
5	1105.581	52.40333	2.63e–14	–17.12019	–13.99996	–15.85386
6	1138.207	47.11469*	2.38e–14	–17.24924	–13.52897	–15.73939
7	1153.119	20.40657	2.96e–14	–17.07226	–12.75195	–15.31889
8	1169.646	21.16586	3.64e–14	–16.92361	–12.00325	–14.92671

Table 4. ***Test Statistics (VAR Lag Order) (Post-Spread COVID-19 Pandemic Period)***

Lag	LogL	LR	FPE	AIC	SC	HQ
0	–12588.45	NA	6.10e+28	80.46934	80.52918	80.49326
1	–10441.83	4210.949	7.90e+22	66.91264	67.27170*	67.05613*
2	–10408.68	63.96913	7.50e+22	66.86056	67.51884	67.12363
3	–10376.22	61.59226	7.15e+22*	66.81293*	67.77042	67.19557
4	–10357.57	34.81028	7.45e+22	66.85346	68.11017	67.35567
5	–10345.16	22.74982	8.08e+22	66.93393	68.48987	67.55572
6	–10324.88	36.54953	8.34e+22	66.96407	68.81922	67.70544
7	–10302.39	39.80767	8.49e+22	66.98011	69.13447	67.84105
8	–10277.72	42.87083*	8.53e+22	66.98224	69.43582	67.96275

The results in Table 5 confirm that at least one cointegration relation is present among the closing values of indices of BRICS economies during the pre-spread COVID-19 pandemic, as H02 is rejected at a 5% significance level.

As per the results of Table 6, in the long run, the performance of Brazil, Russia, and South Africa's financial markets will have a negative impact on the Shanghai Index (China's Financial Market Benchmark) and the performance of Indian financial markets "S&P BSE Sensex" will have a positive effect on the Shanghai Index on average ceteris paribus (as they are just OLS estimates).

VECM China (Shanghai) as a Target Variable

Long-Run Model : Cointegrating Equation

$$ECT_{t-1} = 1.0000 * Shanghai_{t-1} + 1.389855 * BOVESPA_{t-1} - 2.459950 * Sensex_{t-1} + 2.176902 * SA_{t-1} - 0.424884 * MOEX_{t-1} - 21.19888 \quad \ldots\ldots(1)$$

Estimating VECM with Shanghai as a target variable :

$$\Delta Shanghai_t = -0.149153 ECT_{t-1} + 0.190795 \Delta Shanghai_{t-1} + 0.331362 \Delta BOVESPA_{t-1} - 0.067640 \Delta Sensex_{t-1} - 0.165006 \Delta MOEX_{t-1} + 0.003226 \Delta SA_{t-1} - 5.42E\text{-}05 \quad \ldots\ldots (2)$$

$$D(Shanghai) = C(1) * (Shanghai\ (-1) + 1.38985474638 * BOVESPA(-1) - 2.45995011149 * SENSEX\ (-1) + 2.17690249745 * South\ Africa\ (-1) - 0.424883617993 * MOEX\ (-1) - 21.1988800755\ ) + C(2) * D(Shanghai\ (-1)) + C(3) * D(BOVESPA(-1)) + C(4) * D(Sensex(-1)) + C(5) * D(South\ Africa(-1)) + C(6) * D(MOEX(-1)) + C(7) \quad \ldots\ldots(3)$$

Table 5. ***Johansen Cointegration (Unrestricted Rank Test) (Lag 2)***

Trace				
Hypothesized No. of CE(s)	**Eigen Value**	**Trace Statistics**	**0.05 Critical Value**	**Prob. ****
None *	0.292646	74.23421	69.81889	0.0213
At most 1	0.117509	33.03364	47.85613	0.5550
At most 2	0.081953	18.15778	29.79707	0.5544
At most 3	0.064794	7.982479	15.49471	0.4673
At most 4	9.13E-05	0.010870	3.841466	0.9167

Table 6. ***Normalized Cointegration Equation***

Cointegrating Equation(s) : 1086.142			**Log-likelihood**	
Normalized cointegrating coefficients (standard error in parentheses)				
China	**Brazil**	**India**	**Russia**	**South Africa**
1.000000	1.057348	–2.737656	0.266329	2.036669
	(0.22258)	(0.37030)	(0.29450)	(0.34093)

Table 7. ***VECM for Shanghai as a Target Variable***

	Coefficient	Std. Error	*t*-Statistics	Prob.
C(1)	–0.149153	0.034983	–4.263546	0.0000
C(2)	0.190795	0.096801	1.970996	0.0512
C(3)	0.331362	0.114191	2.901830	0.0045
C(4)	–0.067640	0.146816	–0.460710	0.6459
C(5)	0.003226	0.184299	0.017503	0.9861
C(6)	–0.165006	0.134685	–1.225129	0.2231
C(7)	–5.42E-05	0.005381	–0.010065	0.9920
R-squared		0.201680		
Adjusted *R*-squared		0.159291		
F-statistic		4.757874		
Prob(*F*-statistic)		0.000233		

In Table 7, *C*(1), that is, the coefficient of ECT (error correction term) turns out to be negative and significant, implying causality and cointegration among the indices of BRICS economies selected under the study in the long run.

Validating the VECM (China/Shanghai as a Target Variable in the Pre-Spread COVID-19 Pandemic Period): Residual Diagnostics Test

Various tests have been applied to residuals to authenticate the validity of the above-determined model. Residuals' series must be normally distributed, along with the absence of serial correlation and heteroscedasticity in a valid VECM. The VEC residual normality test is applied to check the normality of residuals. The results are obtained where the value of the Jarque – Bera component confirms the normal distribution of residuals at a 5% significance level.

Breusch – Godfrey Serial Correlation LM Test

- **H03 :** No significant serial correlation is present in the residuals.
- **Ha3 :** A significant serial correlation is present in the residuals.

As the prob. chi-square is 0.6772 (Table 8), so Ha3 is rejected, implying the serial correlation problem does not exist in the derived model for the pre-spread COVID-19 pandemic period.

Table 8. ***Breusch – Godfrey Serial Correlation LM Test***

F-statistic	0.174216	Prob.*F*(1,112)	0.6772
Obs**R*-squared	0.186370	Prob.Chi-Square(1)	0.6660

Heteroscedasticity Test

↳ **H04 :** Heteroscedasticity is absent in the residuals.

↳ **Ha4 :** Heteroscedasticity is present in the residuals.

As prob. chi-square is 0.2668 (Table 9), so Ha4 is rejected at a 5% significance level. It implies that heteroscedasticity is not present in the VECM derived under the study for the pre-spread COVID-19 pandemic period.

As per Figure 2, the VECM model for estimating the Shanghai Index closing value in the pre-spread COVID-19 pandemic period is stable. Thus, the derived model is confirmed to be dynamically stable.

Figure 3 depicts some integration among the financial markets of Russia, India, China, and South Africa. However, Brazil's security market is showing deviations in its movement relative to other Asian markets considered under study in the post-COVID-19 pandemic period. Therefore, let's confirm cointegration among the BRICS nation's stock markets during the post-spread COVID-19 pandemic.

Johansen Cointegration Test (Post-Spread COVID-19 Pandemic Period)

↳ **H05 :** No significant cointegration is present in the selected indices of BRICS nations in the post-spread COVID-19 pandemic period.

Table 9. ***Breusch – Pagan – Godfrey Test Statistics***

F-statistic	1.242502	Prob.*F*(10,109)	0.2725
Obs**R*-squared	12.27920	Prob.Chi-Square(10)	0.2668
Scaled explained SS	29.13162	Prob.Chi-Square(10)	0.0012

Figure 2. ***CUSUM Stability Diagnostics Model***

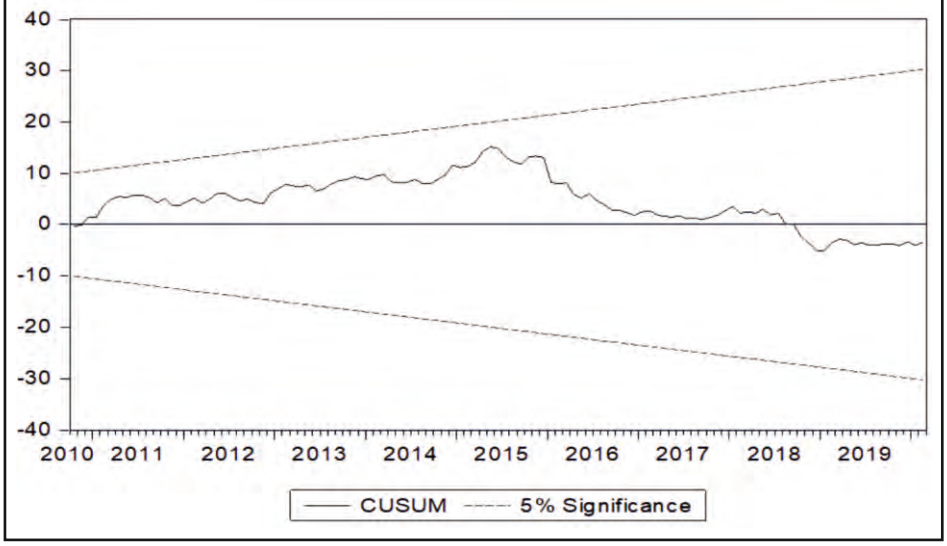

Figure 3. ***Closing Values of BRICS Indices Post-Spread COVID - 19 Pandemic Period***

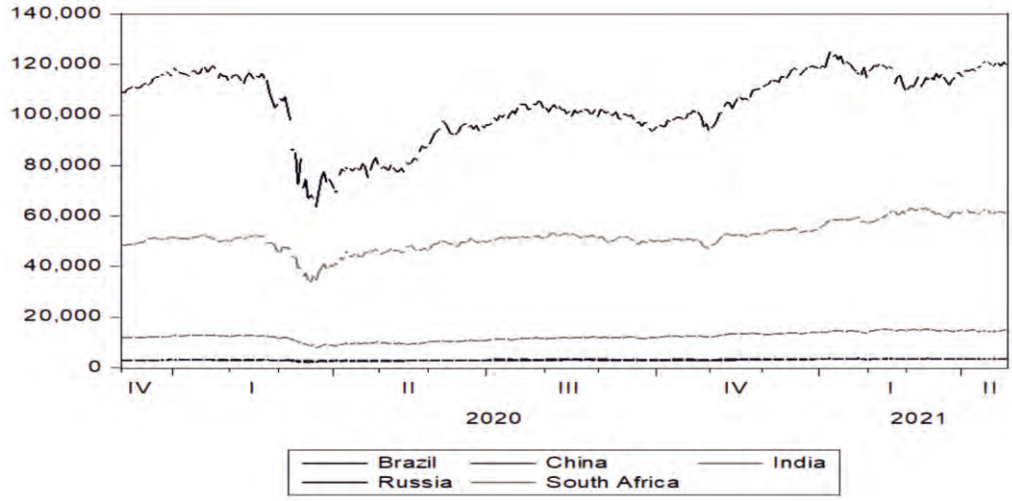

Table 10. ***Johansen Cointegration (Unrestricted Rank Test) (Lag 2)***

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None	0.058797	46.68051	69.81889	0.7729
At most 1	0.044778	26.80504	47.85613	0.8615
At most 2	0.019282	11.77897	29.79707	0.9393
At most 3	0.015031	5.392786	15.49471	0.7658
At most 4	0.001295	0.425052	3.841466	0.5144

↳ **Ha5 :** At least one significant cointegration is present in selected indices of BRICS nations in the post-spread COVID-19 pandemic period.

As per the results presented in Table 10, Ha5 is rejected. Thus, no cointegration is inferred to be present among the indices of BRICS economies post-spread of the COVID-19 pandemic. Hence, the BRICS markets are observed to get operating independently post the spread of the COVID-19 pandemic.

The results of Table 11 depict the covariance and correlations betwixt the stock market pairs of BRICS nations. The results confirm the presence of a positive correlation between the BRICS stock market pairs in the post-spread COVID-19 pandemic period.

Granger Causality Test (Pre-Spread COVID-19 Pandemic Period)

↳ **H06 :** No significant causal association exists among the selected indices pairs of BRICS nations in the pre-spread COVID-19 pandemic period.

↳ **Ha6 :** Significant causal association exists among the selected indices pairs of BRICS nations in the pre-spread COVID-19 pandemic period.

Table 11. ***Covariance Analysis (Post-Spread of COVID-19 Pandemic Period)***

Covariance Correlation	Brazil	China	Russia	India	South Africa
Brazil	1.95E+08				
	1.000000				
China	2240891	67364.97			
	0.618890	1.000000			
Russia	3882842	24051.94	59062.64		
	0.891845	**0.498951**	**0.729164**		
India	21381986	355726.0	500170.7	2938077	
	0.894183	**0.799589**	**0.935010**	1.000000	
South Africa	63709734	1182026	1657508.	8773198	31517465
	0.813468	**0.811212**	**0.946040**	**0.911697**	1.000000

Table 12. ***Granger Causality Test (Pre-Spread COVID-19 Pandemic Period)***

Null Hypotheses :	Obs.	*F*-Statistic	Prob.
CHINESE market is not Granger causing BRAZILIAN market.	2456	3.21870	0.0754
BRAZILIAN market is not Granger causing CHINESE market.		4.51891	**0.0356**
INDIAN market is not Granger causing BRAZILIAN market.	2456	0.35501	0.5524
BRAZILIAN market is not Granger causing INDIAN market.		0.01354	0.9076
RUSSIAN market is not Granger causing BRAZILIAN market.	2456	0.22607	0.6353
BRAZILIAN market is not Granger causing RUSSIAN market.		0.10369	0.748
SOUTH AFRICAN market is not Granger causing BRAZILIAN market.	2456	3.03149	0.0843
BRAZILIAN market is not Granger causing SOUTH AFRICAN market.		0.00131	0.9712
INDIAN market is not Granger causing CHINESE market.	2456	0.87687	0.351
CHINESE market is not Granger causing INDIAN market.		0.61905	0.433
RUSSIAN market is not Granger causing CHINESE market.	2456	0.01712	0.8961
CHINESE market is not Granger causing RUSSIAN market.		0.54107	0.4635
SOUTH AFRICAN market is not Granger causing CHINESE market.	2456	0.19607	0.6587
CHINESE market is not Granger causing SOUTH AFRICAN market.		0.05955	0.8076
RUSSIAN market is not Granger causing INDIAN market.	2456	9.10574	**0.0031**
INDIAN market is not Granger causing RUSSIAN market.		1.22625	0.2704
SOUTH AFRICAN market is not Granger causing INDIAN market.	2456	2.46699	0.119
INDIAN market is not Granger causing SOUTH AFRICAN market.		5.76254	**0.0179**
SOUTH AFRICAN market is not Granger causing RUSSIAN market.	2456	0.37382	0.5421
RUSSIAN market is not Granger causing SOUTH AFRICAN market.		0.02262	0.8807

The Granger causality test statistics presented in Table 12 indicate the presence of unidirectional Granger causality running from the "Brazilian to Chinese" stock market, "Russian to Indian" stock market, and "Indian to South African" stock market as the H06 is rejected. However, BRICS' market pairs such as "India – Brazil,"

"Russia – Brazil," South Africa – Brazil," "India –China," "Russia – China," "South Africa – China," and "South Africa – Russia" are moving independently in the pre-spread COVID-19 pandemic period as Ha6 is rejected for these market pairs.

Granger Causality Test (Post-Spread COVID-19 Pandemic Period)

↳ **H07 :** No significant causal association exists among the selected indices pairs of BRICS nations in the post-spread COVID-19 pandemic period.

↳ **Ha7 :** Significant causal association exists among the selected indices pairs of BRICS nations in the post-spread COVID-19 pandemic period.

The Granger causality test statistics presented in Table 13 indicate the presence of unidirectional Granger causality running from "Brazilian to Russian" and "South African to Chinese" security markets in the post-spread COVID-19 pandemic period as H07 is rejected for them at a 5% significance level. Bi-directional Ganger causality relation is found to be shared among "India–Brazil," "South Africa – Brazil," "Russia – India," "South Africa – India," and "South Africa –Russia" markets post-spread of COVID-19 pandemic as H07 is rejected for

Table 13. ***Granger Causality Test (Post-Spread COVID-19 Pandemic Period)***

Null Hypotheses :	Obs.	*F*-Statistic	Prob.
CHINESE market is not Granger causing BRAZILIAN Market.	334	0.06086	0.941
BRAZILIAN market is not Granger causing CHINESE market.		1.47538	0.2302
INDIAN market is not Granger causing BRAZILIAN market.	334	2.31970	**0.0999**
BRAZILIAN market is not Granger causing INDIAN market.		15.9952	**2.00E-07**
RUSSIAN market is not Granger causing BRAZILIAN market.	334	1.48901	0.2271
BRAZILIAN market is not Granger causing RUSSIAN market.		6.71011	**0.0014**
SOUTH AFRICAN market is not Granger causing BRAZILIAN market.	334	2.99945	**0.0512**
BRAZILIAN market is not Granger causing SOUTH AFRICAN market.		9.00128	**0.0002**
INDIAN market is not Granger causing CHINESE market.	334	1.78099	0.1701
CHINESE market is not Granger causing INDIAN market.		0.19503	0.8229
RUSSIAN market is not Granger causing CHINESE market.	334	1.59094	0.2053
CHINESE market is not Granger causing RUSSIAN market.		0.63383	0.5312
SOUTH AFRICAN market is not Granger causing CHINESE market.	334	3.91402	**0.0209**
CHINESE market is not Granger causing SOUTH AFRICAN market.		0.42728	0.6526
RUSSIAN market is not Granger causing INDIAN market.	334	6.39734	**0.0019**
INDIAN market is not Granger causing RUSSIAN market.		3.25388	**0.0399**
SOUTH AFRICAN market is not Granger causing INDIAN market.	334	5.53840	**0.0043**
INDIAN market is not Granger causing SOUTH AFRICAN market.		2.95287	**0.0536**
SOUTH AFRICAN market is not Granger causing RUSSIAN market.	334	3.81015	**0.0231**
RUSSIAN market is not Granger causing SOUTH AFRICAN market.		7.32886	**0.0008**

them at the 5% significance level. However, market twins, that is, "China – Brazil," "India – China," and "Russia – China," are found independent of each other as Ha7 is rejected for these market pairs.

Discussion and Managerial Implications

The study aims to look into the nature of cointegration among financial markets of BRICS nations and compare the same for pre and post-spread of the COVID-19 pandemic period. It assesses the contribution of the security market performance of Brazil, Russia, India, and South Africa to the performance of China's financial markets, as China is ahead in terms of gross domestic product among the BRICS nations. China is the most economically stable and robust economy, followed by India relative to the other BRICS nations. So, the present study focuses on checking whether any causality is being contributed to the Chinese financial markets by other BRICS nations' financial markets. BRICS financial markets were found to be cointegrated from 2010 – 2019, that is, before the spread of the COVID-19 pandemic, which supports the results of Aggarwal and Raja (2019), Konradsson and Porss (2019), Raja (2018), Dasgupta (2017), Patel (2017), Prakash et al. (2017), and Joshi (2013). Long-run causality is confirmed from Brazil, Russia, India, and South Africa's financial markets to Chinese financial markets, as approved by VECM before the spread of the COVID-19 pandemic. The study results contradict the findings of the research done by Mohammad Irshad and Palaniappan Shanmugam (2017), Ouattara (2017), and Verma and Rani (2015), who confirmed the nonexistence of long-run cointegration amid BRICS security markets from 2005 – 2015, 2005 – 2015, and 2010 – 2014, respectively implying the presence of diversification opportunities for investors. The VECM results confirmed that a change in Brazil and South Africa's stock market index would cause 1.389 times and a 2.176 times decline in the Chinese security market index in the long run. There is negative long-term causality moving from Brazil's and South Africa's stock market's performance to the Chinese (Shanghai) stock market. However, positive long-run causality runs from other BRICS nations' financial markets (except Brazil and South Africa) to the Chinese stock markets before the COVID-19 pandemic.

A 1% change in the closing values of Indian and Russian capital markets will positively impact the closing value of the Chinese index by 2.459 times and 0.424 times, respectively. Thus, positive long-run causality is brought in by Indian and Russian stock markets in the Chinese security markets before the spread of the COVID-19 pandemic worldwide. In the same period, unidirectional causality is observed as running from "Brazil to China," "Russia to India," and "India to South Africa" security markets as per the Granger causality test results. Diversified investments in the BRICS stock markets may prove unprofitable for investors because of the long-term cointegrating equation. The BRICS security markets will revert to an equilibrium level in the long run again despite any short-term drift in the indices. Although cointegration exists among the BRICS security markets, it seems weak as the Granger causality test results do not confirm the presence of causality between the market twins, that is, India – Brazil, Russia –Brazil, South Africa – Brazil, India – China, Russia – China, China – South Africa, and South Africa–Russia from January 2010 – November 2019 (Pre-COVID-19 pandemic period). However, unidirectional causality runs from Russian to Indian and Indian to South African stock markets in the pre-COVID-19 pandemic period. It somehow gives hope to investors to churn financial benefits due to the presence of diversification opportunities.

As per the results, the stock markets of BRICS nations behaved in an absolutely contrary way post spread of the COVID-19 pandemic worldwide. As per Johansen's cointegration statistics, no cointegration equation is present among the financial markets of BRICS nations post-COVID-19 pandemic, that is, from December 1, 2019 – April 30, 2021. The findings of Ouattara (2017) and Verma and Rani (2015) also support the study's findings. BRICS' financial markets were highly correlated as per the covariance analysis but are not cointegrated post spread of the COVID-19 pandemic. Unidirectional causality runs from "South Africa to Brazil" and "Brazil to Russia" stock markets as per the Granger causality statistics. Further, bidirectional causality is found among market pairs such as

"India – Brazil," "Russia – India," "South Africa – India," "South Africa – Brazil," and "South Africa – Russia." Tripathy (2015) and Verma and Rani (2015) also confirmed similar results. The BRICS markets share no cointegration post spread of the COVID-19 pandemic, but they share some unidirectional and bidirectional causality relations.

Thus, the individual and institutional investors of BRICS nations can reduce their country-specific risks by investing in other BRICS stock markets. They can leverage the inefficiencies of the BRICS stock markets, earn higher returns, and diversify risks. The brokers, individual & institutional investors, other stock market players, HNIs, and academicians can benefit from the study results and strategize their investments and hedging movements. They can assess the potential returns on their diversified portfolios due to the absence of cointegration among BRICS stock markets. The study reveals that the COVID-19 pandemic changed the behavior of domestic and cross-border individuals, businesses, industries, and nations at large. It has also modified the behavior and movements of stock markets and the strategic moves of its players. Thus, the present study results may assist the individual and institutional investors of BRICS and other nations in devising their hedging strategies during the ongoing COVID-19 pandemic. In addition, the study can lay the basis for making policies related to stock market regulations. The study findings may prove worthwhile for the regulatory bodies of BRICS economies in formulating economic policies specifically related to financial markets and capital flows.

Conclusion

Portfolio hedging is the primary reason for cross-border investments. However, this benefit is taken away by the presence of financial integration among different countries' markets. The present study results make it evident that diversified investment in BRICS markets by investors will bring lots of monetary benefits in the long and short-run due to the absence of any long-term and short-term financial nexus between them post spread of the COVID-19 pandemic.

With the surge of COVID-19 cases in various countries at different rates, the stock markets and other macro indicators of different countries behave randomly and unrelatedly. Such dissociation resulting from the uncertain present COVID-19 pandemic era has brought many profitable opportunities for foreign and domestic individual and institutional investors. It is further confirmed that the Indian stock market shares no causal relation with the Chinese stock markets, implying that Indian investors can reap extraordinary returns by diversifying their investments in the security market of China. The results show that the Indian security market shares no long-term equilibrium with other BRICS nations' stock markets, which means investors, that is, individual, institutional, public, and HNIs, can earn extraordinary or high returns in BRICS nations due to the absence of long-run and short-run cointegration in the ongoing post-COVID-19 pandemic period. The study results motivate investors to reap high and unlimited returns by diversifying portfolios amongst the studied financial markets post spread of the COVID-19 pandemic, which was otherwise not possible in the pre-COVID-19 pandemic period due to existing long-run cointegration among the BRICS stock markets.

Limitations of the Study and Scope for Future Research

In the present study, only one benchmark, that is, the stock market index, is considered for five Asian countries, that is, BRICS. However, this may be a limitation of the present study as the chosen benchmark might not depict the actual view of the country's overall stock market movements and sentiments of its market players.

Researchers can extend the present study to assess the cointegration and association of other countries' stock markets, currency markets, and commodity markets. The researchers can develop the present study by considering different time frames and data of other indices of BRICS and other nations. The present study can

further be extended to identify the quantum of the financial risks involved within each BRICS stock markets so that cross-border investors can formulate their investment portfolio strategies that will provide the highest returns with managed risks.

Author's Contribution

Dr. Razia Nagina conceived the idea and developed qualitative and quantitative design to undertake the empirical study. She extracted research papers with high repute, filtered these based on keywords, and generated concepts and codes relevant to the study design. The numerical computations were done by her using EViews 11. She also wrote and proofread the manuscript.

Conflict of Interest

The author certifies that she has no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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