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INTEGRATION AND DYNAMIC LINKAGES OF THE INDIAN STOCK MARKET WITH BRIC – AN EMPIRICAL STUDY

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ABSTRACT

The interrelationships, interdependencies, integration, and dynamic linkages in between countries, regions including BRIC, country-region, and developing-developed stock markets had been thoroughly researched in the literature. This study aims at investigating above relationships both in short and long-run with special reference to India. It undertakes daily closing values of the BRIC indices from 1st January 2003 to 31st December 2012. This study has used Jarque-Bera test, and ADF and PP tests for judging the normality and stationarity of the data series. Based on the above results this study undertakes Johansen and Juselius's and Engle and Granger's cointegration tests, and pairwise Granger causality tests to investigate short and long-run interrelationships and integration of the BRIC stock markets. To make this study more reliable the Vector Autoregression in the form of Impulse response functions and Variance Decomposition analysis are also used. This study has found that they are non-normal and non-stationary at level, but integrated of order 1 [i.e., I(1)]. It has found only one cointegration, i.e., long-run relationships and also short-run bidirectional Granger relationships in between the Indian and Brazilian stock markets. Also, the Chinese stock market Granger causes the Brazilian stock market which in turn has a causal effect on the Russian stock market. Based on the above results, it is found that the Indian stock market has strong impact on Brazilian and Russian stock markets. The interdependencies (mainly on India and China) and dynamic linkages are also evident in the BRIC stock markets. Overall, this study has found that BRIC stock markets are the most favourable destination for global investors in the coming future and among the BRIC the Indian stock market has the dominance.

Keywords: BRIC stock markets, Integration, Dynamic linkages, ADF and PP tests, JJ and Engle-Granger cointegration tests, Pairwise Granger causality tests, Impulse response functions, Variance decomposition analysis.

JEL Classification: C1, G1

1. INTRODUCTION

Post 1997-98 Asian crisis one of the most interesting and frequently research subjects among the researchers, policymakers, and global investors internationally is integration, interrelationship, interdependencies, and dynamic linkages of the stock markets around the globe. Different empirical studies had been undertaken throughout the world investigating the above - country-wise (Eun and Shim, 1989; Lee and Kim, 1994; Chow *et al.*, 2011), region vs. country-wise (Shachmurove, 2006; An and Brown, 2010; Sheu and Liao, 2011), region-wise (e.g., BRIC region (Gupta, 2011; Sharma *et al.*, 2013), trade-relationship-wise (Valadkhani and Chancharat, 2008), nature-wise (i.e., developing and/or emerging vs. developed (Sharma and Kennedy, 1977; Groenewold *et al.*, 2004; Wong *et al.*, 2005; Li, 2007; Koźluk, 2008; Abas, 2009; Khan, 2011), with different objectives (Kumar, 2011) and also under divergent economic situations, events, and turmoils in the last few decades.

As the world becomes increasingly financially interconnected, it is important for the different stakeholders, especially international equity-market investors to understand the relationships that exist between certain economies in order to gain most from effective diversification strategies by adjusting their portfolios accordingly and timely. So, the most emerging economies (in terms of their growth numbers) are catching the eyes of them as the most preferable investment destination for this decade and beyond. In this regard, the BRIC (i.e., Brazil, Russia, India, and China) countries or alternatively the "Big Four" (O'Neill, 2001) has emerged the best epicenter for international investors. This is evident by the market value of publicly traded shares of BRIC (Brazil - \$2.769 trillion_{2011} and \$2.193trillion_{2010}, Russia - \$1.005 trillion_{2010}, India - \$1.452 trillion_{2011} and \$1.25 trillion_{2010}, and China - \$4.763 trillion_{2010} [all as on 31st December of the respective year]) (Source: CIA World Fact Book and Other Sources) countries. Amidst economic recession in most parts of the world, BRIC (Brazil – 2.8%$_{2011}$ and 7.5%$_{2010}$, Russia – 4.3%$_{2011}$ and 4%$_{2010}$, India – 7.8%$_{2011}$ and 10.1%$_{2010}$, and China – 9.5%$_{2011}$ and 10.1%$_{2010}$ [all est. GDP real growth rate]) (Source: CIA World Fact Book and Other Sources) countries have been showing a continuous economic uptrend. The industrial production growth rate, exports figure, reserves of foreign exchange and gold, etc. are also showing the future potential of this region over other groups in the world.

Another very strong reason to select BRIC for this study is their already existing bilateral trade relationships. For example, in case of India China is the largest importer (12.4% of total imports in 2010), and the third largest exporter (8.1% of total exports in 2010). In case of Brazil China is the second largest importer (14.1% of total imports in 2010), and the largest exporter (15.2% of total exports in 2010). In case of Russia also China is the second largest importer (13.5% of total imports in 2010), and the fourth largest exporter (5.4% of total exports in 2010). Also, by 2020 China, India, and Brazil are projected to become three of the largest five economies in the world with Russia and Indonesia also in the top ten (see Table 1).

Table-1. Largest Economies based on GDP forecast for 2020 (in \$trn)

2000	**\$trn**	**2010**	**\$trn**	**2020**	**\$trn**
US	10.0	US ↔	14.6	China ↑	24.6
Japan	4.7	China ↑	5.9	US ↓	23.3
Germany	1.9	Japan ↓	5.6	India →	9.6
UK	1.5	Germany ↓	3.3	Japan ↓	6.0
France	1.3	France ↔	2.6	Brazil ↑	5.1
China	1.2	UK ↓	2.3	Germany ↓	5.0
Italy	1.1	Italy ↔	2.0	France ↓	3.9
Canada	0.7	Brazil ↑	2.0	Russia ↑	3.5
Brazil	0.6	Canada ↓	1.6	UK ↓	3.4
Mexico	0.6	Russia →	1.5	Indonesia →	3.2

→ entering in ↔ same rank as before ↑ up the rank ↓ down the rank

Source: Standard Chartered 'The Super-Cycle Report'

So, studying the interrelationships, interdependencies, and integration of their stock markets with the dynamic linkages is the most timely endeavour on my part under this study.

More specifically, this study aims at finding the short and long-run relationships in between the BRIC stock markets. Which of the BRIC markets is influencing, and causing the movement of the benchmark indices of other markets in short-to-long run will also be studied here. Additionally, dynamic linkages in between those markets will be investigated to validate the above results. At the end, this study will conclude by pointing out the most preferable investment destination among the BRIC countries based on empirical results.

To work on the above objectives, this study uses graphical presentations, descriptive statistics (to state the nature and normality of the data series), correlation test results, Augmented Dickey-

Fuller (ADF) (Dickey and Fuller, 1979; 1981) tests and Phillips and Perron (1988) tests (to find out the stationary nature or unit root issues), Johansen and Juselius (1990) cointegration technique and Engle and Granger (1987) and Granger (1969) causality test. In case of more than two variables, Granger (1969) causality test may not give authentic results. So, I have also used Vector Auto regression (VAR) technique to detect causality under this study. Impulse Response Functions (IRFs) and Variance Decomposition Analysis (VDA) techniques are employed here for the interpretation of the VAR model. The study period is taken from 1st January 2003 to 31st December 2012, i.e., 10 years on the trot.

The rest of the paper is organized as follows. A survey of the existing literature including empirical evidences on the relevant theory, short and long-run interrelationships, interdependencies, integration, and dynamic linkages in between BRIC stock markets is conducted in Section 2. Section 3 presents data descriptions for this study and discusses research methodology used for investigation and analysis purposes. Section 4 reports empirical results and subsequent discussions followed by conclusion in Section 5.

2. LITERATURE REVIEW

The interrelationships, interdependencies, integration, and dynamic linkages of stock markets all over the world are a vastly-researched subject. But, the question is what we mean by financial integration and how this impact stock markets. Generally financial integration ensures the law of one price to financial assets with the same risk (Adam *et al.*, 2002). Thus, in perfectly integrated markets, all assets with identical risk exposure also command identical expected returns (Campbell and Hamao, 1992). So, a high degree of integration between national markets minimizes the potential benefits from international diversification (Bessler and Yang, 2003).

For this study as I am undertaking the BRIC countries, I highlight only the relevant studies in this regard with a brief global background.

Earlier studies by Ripley (1973), Lessard (1976), and Hilliard (1979) generally found low correlations between national stock markets, supporting the benefits of international diversification. The October 1987 crash made people realize that various national equity markets are so closely connected as the developed markets like the US stock market exert a strong influence on other markets. Mukhopadhyay (2009) found that market integration is more prominent among markets which are at comparable development stage.

Applying the VAR model, Eun and Shim (1989) found evidence of comovements between the US stock market and other world equity markets. Lee and Kim (1994) examined the effect of the October 1987 crash and concluded that national stock markets became more interrelated after the crash and found that the comovements among national stock markets were stronger when the US stock market is more volatile.

In Indian context, in one of the earliest studies Sharma and Kennedy (1977) examined the price behaviour of the Indian market with the US and UK markets and concluded that the behaviour of the Indian market is statistically indistinguishable from them and also found no evidence of systematic cyclical component or periodicity for these markets.

Groenewold *et al.* (2004) and Li (2007) pointed out the relative isolation of Chinese stock markets from the world markets. Koźluk (2008) concluded that Chinese stock markets are "almost completely separated from global affairs," but "strongly inter-related" themselves. However, more recently Chow *et al.* (2011) found evidence of rising integration of the Chinese and world stock markets, measured in terms of comovements of Shanghai and New York Stock exchange prices.

The Brazilian stock market's integration can be traced to studies by Yang *et al.* (2004), Fujii (2005), Khalid and Rajaguru (2007), Rivas *et al.* (2008), Aktan *et al.* (2009), etc. However, lack of relationship is found in the studies that utilize cointegrating techniques (Tabak and Lima, 2002; Ozdemir *et al.*, 2009).

Koźluk (2008) provided one of the rare studies that includes the stock markets of both Russia and China as part of a much broader analysis (135 indices for 75 countries in total from the early 1990s to 2007). The results of the approximate factor model (which allows the identification of global versus regional factors) showed that while Russian stock markets behave like a "typical"

emerging market, i.e., characterized by rising integration with world markets, China's A-share and B-share markets move largely independently from global markets.

Tirkkonen (2008) by employing VAR and cointegration methods argued that the Russian stock markets are relatively isolated from the global markets such as the US, China, Japan, UK, Germany, as well as nearby Poland and the Czech Republic.

Abas (2009) examined the linkages of the two leading emerging markets, i.e., the Chinese and Indian markets with other developed markets, i.e., the US, the UK, Japan and Hong Kong. They found that the Chinese and Indian markets are correlated with all four developed markets under study. Both markets have at least had unilateral causality with all four developed markets. The empirical results suggested that the benefits of any short-term diversification, or speculative activities, are limited between them.

Shachmurove (2006) analyzed the dynamic interrelationships among the stock exchanges of the US and of the four Emerging Tigers of the Twenty First Century, namely Brazil, China, India, and Russia. Using VAR Models and daily data that span from May 1995 until October 2005, the dynamic linkages among these markets were studied. It was found that the Brazilian stock market returns are affected to a large extent by other stock markets. This finding is true also for the Russian stock market returns, although to a lesser extent. The Chinese and Indian markets are much less affected by dynamic linkages originating from other markets. The Chinese stock exchange seems the most isolated from exogenous disturbances. Moreover, this market is the least influenced by the American stock market. This result seems to encourage a larger extent of American purchases and activities in the Chinese stock markets in order to improve diversification.

Bhar and Nikolova (2009) explored the level of cointegration of the BRIC with their respective regions and the world in the post-liberalization period, and found that India has the highest level of integration on a regional and world level amongst the BRIC countries followed by Brazil, Russia, and lastly China. The study also suggested the existence of diversification opportunities for China, given its closed nature of the financial system.

Bora *et al.* (2009) examined the emerging market indices of Brazil, Russia, India, China, and Argentina (BRICA) and investigated the linkages among the stock markets of the BRICA countries and their relations with the US market, by employing the VAR techniques to model the interdependencies and Granger causality test to find evidence of a short-run relationship between these markets. The findings showed that the US market had a significant effect on all BRICA countries in the same trading day.

Chittedi (2009) examined the integration of the stock markets among the BRIC economies and their integration with the developed countries' stock markets such as the US, UK, and Japan using Johansen's cointegration, Granger's causality test and Error Correction Mechanism/Model (ECM). It was found that there is cointegration between BRIC countries and developed countries, namely, the USA, UK, and Japan. The results of ECM revealed that the SENSEX, NIKKEI, FTSE and BOVESPA are significant. It implies that these markets share the forces of short-run adjustment to long-run equilibrium.

An and Brown (2010) examined the comovements of the weekly and monthly index returns of the US, Brazil, Russia, India, and China stock markets during October 13, 1995-October 13, 2009. Their findings indicated that there is some cointegration between the US and China, while there is no cointegration between the US and the other emerging markets by themselves. Therefore, all of the BRIC stock markets, with the exception of China provide attractive portfolio diversification opportunities for global investors.

Gupta (2011) analyzed the dynamic relationship among the emerging countries specially BRIC countries in condition of financial turmoil. The time span from the year 2008 till now seemed to be full of financial tantrum – Sub Prime Crisis, US debt Crisis and European debt crisis. He attempted to quantify the interrelationship between these promising countries. It proved that the economy of India, Russia, and China Granger causes the Brazil economy but the converse is not true. But Russia does not granger cause the Indian economy but Indian economy granger causes the Russian economy. Granger causality test gives statistic that china economy have the bidirectional causality

with India and Russia. Thus Chinese economy is largely interdependent of Indian and Russian Economy.

The study of Sheu and Liao (2011) investigated the evolving pattern of integration and Granger causality relationships between the developed US and developing BRIC stock markets. The empirical results demonstrated that the stock markets of Brazil, Russia, and China have begun exerting significant influences on the Dow Jones to some extent after 2006, and the Dow Jones index continues to play a dominant role and increasingly, Granger causing shifts in the emerging markets of Russia, India, and China. The findings pointed out that the time-varying nature of the non-linear cointegration and Granger causality relationships, and also indicated that the potential benefits from international risk diversification may have gradually diminished between these studied markets.

Sharma *et al.* (2013) studied the interlinkages between Brazil, Russia, India, China, and South Africa (BRICS) stock markets with the help of benchmark indices of these stock exchanges. The study revealed that the BRICS stock markets were influenced by each other, but not to a great extent. It implies that there exists opportunities for diversification of the investors among the stock exchanges of BRICS. It was also observed that there are domestic factors (macroeconomic variables) that influence the stock markets.

However, Awokuse *et al.* (2009) pointed out that although empirical evidence from previous studies, using conventional linear cointegration models has shown stock market integration in some regions, the existing empirical evidence remains inconclusive and there are conflicting results regarding the nature of dynamic interdependence between developed and/or emerging markets.

Thus, it is quite clear from the above survey that empirical literature on stock market integration is abundant and results vary according to variable specification, research methodology adopted, participating countries, and period of such study. In this regard, generalization is made complex. Another critical point is that some such studies which analyze a group of countries provide only general conclusions or overall trends rather than results for each country. Also, investigation of the dynamics of the process of integration should reveal the direction of the integration, i.e., whether the markets are becoming more or less integrated during the period of study. This study has looked into the above loopholes in detail. Also, the impact of other BRIC countries on the Indian stock market for the whole study period and its dynamic linkages with them has also been thoroughly examined.

3. DATA AND METHODOLOGY

I have used daily closing price data from 1st January 2003 to 31st December 2012 (2,630 observations in total for all the BRIC indices) of the Bolsa Oficial de Valores de São Paula (BOVESPA Index [i.e., BOVESPA here]), Russian Trading System (RTS Index [i.e., RTS here]), Bombay Stock Exchange (BSE SENSEX [i.e., SENSEX here]), and Shanghai Stock Exchange (SSE Composite Index [i.e., SHCO here]) respectively for representing the BRIC countries. The data has been collected from www.econstat.com. Since this study is based on the daily indices closing prices rather than the intra-day prices, it won't add any value by considering the real trading time of different selected exchanges all over the world.

The two most important criteria to examine when one deals with indices data series is that of normality and stationarity. The Jarque-Bera test (JB) (Gujarati, 2003) is used here to test whether stock indices of the BRIC countries individually follow the normal probability distribution. This test computes the skewness and kurtosis measures and uses the following test statistics:

$$JB= n [S^2/6 + (K-3)^2/24] \quad (1)$$

Where, n = sample size, S = skewness coefficient, and K = kurtosis coefficient. For a normally distributes variable, S = 0 and K = 3. Therefore, the JB test of normality is a test of the joint hypothesis that S and K are 0 and 3 respectively.

To avoid the problem of spurious regressions, it is also necessary to test the order of integration of each index in the model, in order to establish whether it is non-stationary and how many times the index values need to be differenced such that a stationary series can be recovered. The ADF (Dickey and Fuller, 1979; 1981) and Phillips and Perron (1988) unit-root tests are employed in this study.

In order to test for unit roots through ADF tests, I use the following equation:

$$\Delta y_t = \alpha_0 + \lambda y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t \quad (2)$$

In the above equation, α_0 is a constant, λ is the coefficient of y_{t-1}, p is the lag order of autoregressive process, $\Delta y_t = y_t - y_{t-1}$ are first differences of y_t, y_{t-1} are lagged values of order one of y_t, Δy_{t-i} are changes in lagged values, and u_t is white noise.

So, I test the null hypothesis of $\lambda = 0$ against the alternative hypothesis of $\lambda < 0$. The null hypothesis of non-stationarity is rejected if λ is negative and significantly different from zero.

The test regression for the PP tests is the AR(1) process in which the following equation is used:

$$\Delta Y_t = b_0 + \beta Y_{t-1} + e_t \quad (3)$$

In the above equation, where Y_t represents a stock price series (in logarithmic form), b_0 is a constant, and e_t are error terms. The PP test statistics are based on the Phillips Z-Test.

Generally, Correlation analysis is used for judging short-run dynamic linkages and integration, and Granger causality test is employed to find the cause and effect relationships among international stock markets. So, this study applies a simple correlation test to measure the strength and direction of the association between the selected stock indices. It also implies the interdependency and co-movement of BRIC stock markets. However, Leong and Felmingham (2003) criticized the reliability of correlation test because correlation coefficients are known to be upward-biased if the stock indices have heteroskedastic elements. Therefore, investigation of these stock markets' integration and dynamic linkages is to be extended by employing Granger (1969) pairwise causality test.

The Granger (1969) causality test establishes short-run relationships between selected indices. It is a bivariate analysis and involves estimates X(Y→X) and Y(X→Y) by using following pair of regressions:

$$Y_t = \beta_0 + \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{i=1}^{n} \beta_i Y_{t-i} + \varepsilon_{1t} \quad (4)$$

$$X_t = \lambda_0 + \sum_{i=1}^{n} \delta_i Y_{t-i} + \sum_{i=1}^{n} \lambda_i X_{t-i} + \varepsilon_{2t} \quad (5)$$

The null hypothesis is $\alpha_i = \delta_i = 0$. If the α_i is statistically significant but δ_i is not then it means X causes Y, and in the reverse case Y causes X. But if both are significant then causality runs both ways. Hence, if the lagged values of one index values do not yield a statistically significant relationship, then it can be stated that such values do not Granger cause the other index closing values. Thus, the F-test value is the standard one in this regard.

The VAR method requires the index values to be stationary at levels to obtain proper estimates of the coefficients. In empirical applications, the main uses of the VAR are the impulse response analysis, variance decomposition, and Granger causality tests.

Using a VAR model, this study also analyses the degree to which a change in one country's index price series exerts an influence on a change in other countries' series, and the time path of the latter. Hence, the major difference between these interdependencies, and the earlier comovement among BRIC stock price series, lies in the fact that this VAR test examines the dynamic structure

of stock price developments. Thus, the study looks at the effect that a shock (through an innovation or news) in one stock market has on others.

I have applied the VDA here to quantify the extent up to which the four BRIC stock market indices are influenced by each other.

IRF analysis is conducted here to obtain additional insights into the transmitting mechanism of the stock market movements in the BRIC stock markets to the Indian stock market. The pattern of dynamic responses of each of the four BRIC stock markets to a shock, i.e., positive residuals of one standard deviation unit in the corresponding stock market, is examined.

Whether the data is stationary at levels or non-stationary at levels but stationary when differenced, i.e., I(1), determination of the proper multivariate time series analysis technique has to be done. Given the I(1) properties of all the BRIC stock market indices, the cointegration (i.e., long-run) relationships between them can then be tested. In this study, the Johansen and Juselius (1990) Trace and Maximum Eigenvalue tests, and Engle and Granger (1987) cointegration test are employed to test the long-run relationships among the stock market indices of the BRIC. If two or more stock market price indices are found to be cointegrated, it implies that there is a long-run equilibrium relationship between them, and even though the price series themselves may be non-stationary, they will nevertheless move closely together over time.

In order to fulfill the above objective, the following VECM-specific equation is used:

$$\Delta y_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + \varepsilon_t \quad (6)$$

Where:

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j \quad \text{and} \quad \Pi = -I + \sum_{i=1}^{p} A_i \quad (7)$$

The Trace and Maximum Eigenvalue tests can be used to find the number of cointegrating vectors. The equations for those tests are as follows:

$$J_{trace} = -T \sum_{i=1+r}^{n} \ln(1 - \hat{\lambda}_i) \quad (8)$$

$$J_{max} = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (9)$$

Here T is the sample size and $\hat{\lambda}_i$ is the ith largest canonical correlation. The Trace test tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. The maximum Eigenvalue test, on the other hand, tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of r+1 cointegrating vectors. If the test statistic is greater than the critical value from the Johansens's tables, I reject the null hypothesis that there are r cointegrating vectors in favour of the alternative hypothesis under the said tests in line with Brooks (2002).

Johansen's cointegration test is sensitive to the lag length (Enders and Todd, 2004). I have employed Akaike Information Criteria (AIC) and Schwarz Information Criterion (SIC) to select the appropriate lag length under this study.

For applying Engle-Granger test, two (2) time series X_t and Y_t which are integrated of order one (1) [i.e. I (1)] are regressed using the following equation:

$$Y_t = \beta_1 + \beta_2 X_t + \mu_t \quad (10)$$

Now, if the residual series of this regression is subject to unit-root tests, and the results show that it is stationary, i.e., I(0), it means that X_t and Y_t are co-integrated. Although X_t and Y_t are

individually I(1), i.e., they have stochastic trends, their linear combination is I(0). Therefore, the linear combination cancels out the stochastic trends in the two indices series. To perform the cointegration analysis, the index for the Indian stock market, i.e., the BSE SENSEX, is regressed on other indices (taking one at a time) and ADF and PP tests are applied on the residual series.

4. EMPIRICAL RESULTS

This study has used graphical presentations (see Fig. 1), and descriptive statistics results to find out the normality of the indices data series.

Figure-1. BRIC Indices

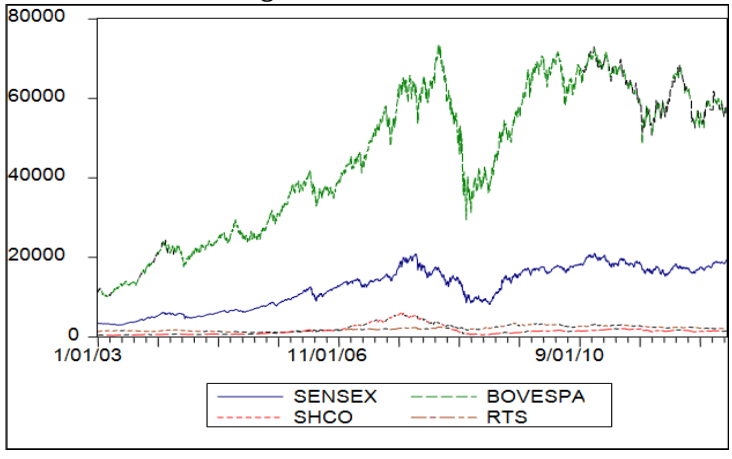


Fig. 1 points out that the BRIC indices are very volatile in their movement. Brazilian and Indian stock markets are more volatile than their Russian and Chinese counterparts. Also, there is clear case of comovements in the long and short-run for the BRIC stock markets.

Table-2. Descriptive Statistics

Particulars	SENSEX	SHCO	BOVESPA	RTS
Mean	12493.75	2348.314	45086.62	1283.061
Median	13919.70	2260.850	49229.50	1403.485
Maximum	21005.00	6092.060	73517.00	2487.920
Minimum	2924.030	1011.500	9995.000	336.0800
Standard Deviation	5311.601	1027.907	18424.21	560.3649
Skewness	-0.319391	1.144841	-0.295231	-0.036790
Kurtosis	1.685348	4.297562	1.725203	1.785645
Jarque-Bera	232.1501	752.6590	214.4810	160.8346
Probability	0.000000	0.000000	0.000000	0.000000

Table 2 represents the summary statistics of the indices values under this study. The average daily indices value for all BRIC indices during the study period with a high standard deviation has implied highly volatile stock markets. The value of skewness of the above variables has pointed out that except RTS the other variables have higher values during the study period. It indicates a deviation from normal distribution of the data series and volatility in them. The value of kurtosis has pointed out that SHCO has leptokurtic distribution (i.e., >3) with values concentrated around the mean and thicker tails. This means high probability for extreme values which is observed from the above table. The kurtosis value of others indicates platykurtic distribution (i.e., <3) and the values are wider spread around the mean. Jarque-Bera test statistic measures the difference of the skewness and kurtosis of the data series with those from the normal distribution.

This study has also used the ADF and PP tests to find out the stationarity, i.e., whether indices data series contain any unit-root or not.

Table-3. ADF and PP Tests Results (with Intercept and no Trend)

ADF Tests				PP Tests			
Variables	**Level**	**1st Difference**	**Conclusion**	**Variables**	**Level**	**1st Difference**	**Conclusion**
SENSEX	–1.353191	–34.78870	I(1)	SENSEX	–1.343328	–48.35885	I(1)
SHCO	–1.357239	–37.35219	I(1)	SHCO	–1.346478	–51.44531	I(1)
BOVESPA	–1.744724	–37.12087	I(1)	BOVESPA	–1.766879	–53.08664	I(1)
RTS	–1.828279	–33.90666	I(1)	RTS	–1.781739	–45.65589	I(1)

Level - Critical value at 1% significance level is –3.4359, at 5% significance level is –2.8632* and at 10% significance level is –2.5677**
1st Difference - Critical value at 1% significance level is –3.4359 and at 5% significance level is –2.8632# and at 10% significance level is –2.5677##

The results in Table 3 has indicated the presence of a unit-root in the levels of all indices. There is no evidence to support the presence of a unit-root in first differences of the BRIC stock market indices. Hence, changes in stock prices are stationary. In other words, all stock market indices series are integrated of order one [i.e., I(1)]. Thus, the uniqueness of a unit-root in the stock price level is confirmed.
This study uses simple correlation tests results, Granger causality tests results, and VAR results to find out short-run dynamic linkages and integration, and any possible causal relationships in between BRIC markets in the short-run.

Table-4. Correlation Results

		SENSEX	**SHCO**	**BOVESPA**	**RTS**
SENSEX	Pearson Correlation	1	.698**	.972**	.839**
	Sig. (2-tailed)		.000	.000	.000
SHCO	Pearson Correlation	.698**	1	.704**	.735**
	Sig. (2-tailed)	.000		.000	.000
BOVESPA	Pearson Correlation	.972**	.704**	1	.818**
	Sig. (2-tailed)	.000	.000		.000
RTS	Pearson Correlation	.839**	.735**	.818**	1
	Sig. (2-tailed)	.000	.000	.000	

** Correlation is significant at the 0.01 level (2-tailed)

Table 4 has pointed out that all the BRIC stock markets are positively correlated with a high level of significance. Especially, the BSE SENSEX Index has very high correlations (i.e., more than 0.8 with a significance of .000) with the BOVESPA and RTS Index. This is in line with the earlier graphical results.

Table-5. Lag Length Selection

Lag	**AIC**	**SIC**
1	-64091.95	-64091.91
2	–63836.06	-63835.98
3	–63754.99	-63754.88
4	–63676.51	–63676.36

This study has applied Granger causality test of Granger (1969) with 1 lag (see Table 5).

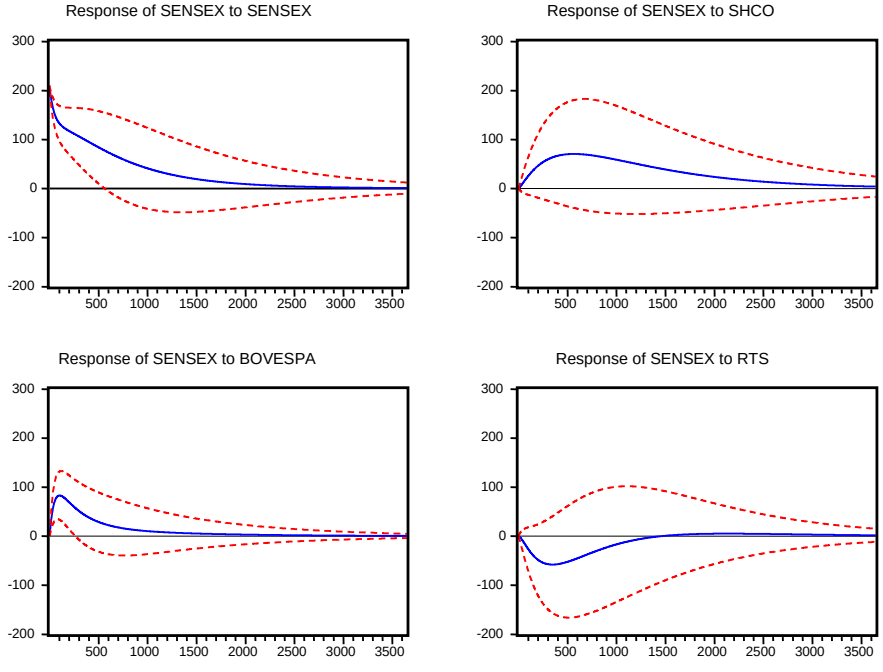
Table-6. Granger Causality Tests Results

Null Hypothesis:	Observations	F-statistic	Probability
SHCO does not Granger Cause SENSEX	2606	0.38771	0.53356
SENSEX does not Granger Cause SHCO		0.00515	0.94277
BOVESPA does not Granger Cause SENSEX	2606	12.5661	0.00040
SENSEX does not Granger Cause BOVESPA		5.57289	0.01831
RTS does not Granger Cause SENSEX	2606	0.07476	0.78454
SENSEX does not Granger Cause RTS		1.53590	0.21534
BOVESPA does not Granger Cause SHCO	2606	0.03657	0.84835
SHCO does not Granger Cause BOVESPA		2.83497	0.09235
RTS does not Granger Cause SHCO	2606	0.24702	0.61923
SHCO does not Granger Cause RTS		1.35870	0.24387
RTS does not Granger Cause BOVESPA	2606	0.51180	0.47442
BOVESPA does not Granger Cause RTS		3.68813	0.05491

Results from that test are shown in Table 6. It has shown no short-run causal relationship in between SENSEX and SHCO and also in between SENSEX and RTS. However, the Indian stock market represented by the BSE SENSEX Index has short-run causal relationships in both ways with the Brazilian stock market, i.e., the BOVESPA Index. It is also found that SHCO has some sort of short-run relationship with the Brazilian stock market and also BOVESPA granger causes unidirectionally the RTS. Overall, this study has found some unidirectional and bi-directional Granger causality effect in between the selected BRIC stock markets.

The pattern of dynamic responses of each of the four BRIC stock markets to a shock, i.e., positive residuals of one standard deviation unit in the Indian stock market, has been examined first. Fig. 2 has presented the results.

Figure-2. Response to One S.D. Innovations ± 2 S.E.



One thing to note is that a different ordering of the variables in the system may provide different results for Choleski decomposition of the innovation matrix, so the arbitrariness of the ordering can be subject to criticism. In the current study, the causal ordering of the variables is

SENSEX first and then the other BRIC stock market indices in order of China, Brazil, and Russia. Figure 2 and 3 provide plots of the time paths of the impulse responses for those four BRIC stock markets to a market shock during the study period (Figure 2) and also impulse responses of SENSEX to the corresponding market shock in BRIC markets (Figure 3) at the finest time scale (d1). The solid line plots the point estimates of the impulse responses of the Indian stock market index (i.e., the BSE SENSEX Index) to standard deviation shocks of BRIC markets. The dotted lines in Fig. are the two standard deviation bands around the points estimates.

Figure-3. Response of BRIC Indices to One S.D. Innovations (Long-run)

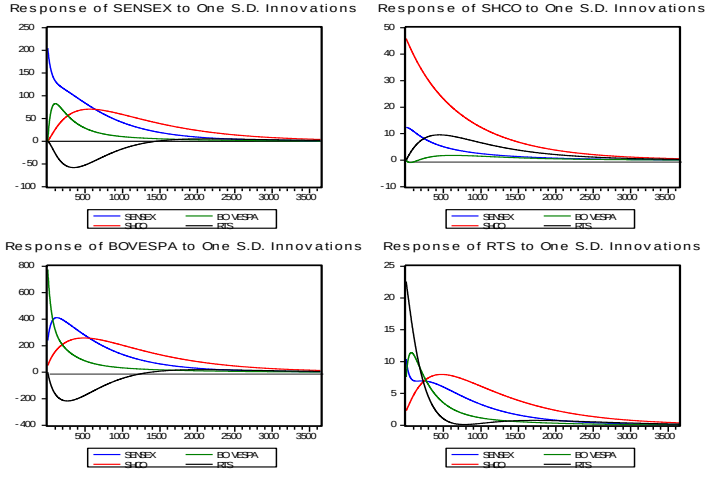


Figure-4. Response of BRIC Indices to One S.D. Innovations (Short-run)

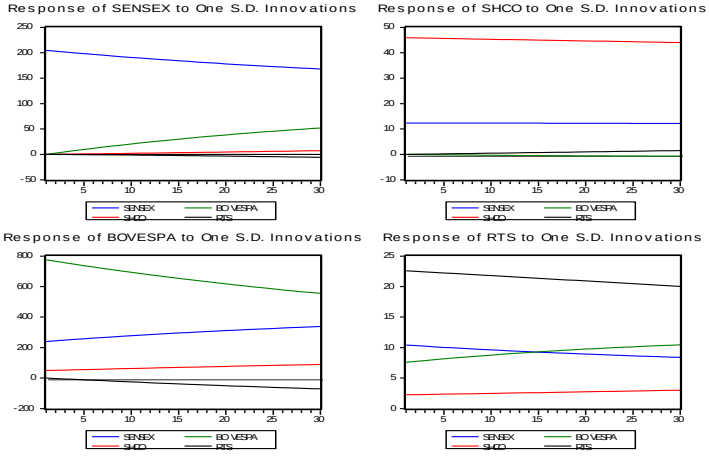


Fig. 3 and 4 have pointed out the responses of the BRIC countries to the shocks of other ones. The dynamic linkages of the SENSEX, SHCO, BOVESPA, and RTS to BRIC indices are quite clear from them. A positive one standard deviation shock to the BRIC stock market indices has a negative effect to the Indian stock market throughout the study period both in the short and long-run. A similar dynamic response has also observed in case of the Chinese stock market's SSE Index. BOVESPA and RTS have also shown similar types of dynamic linkages in this study. The minor difference between impulse responses of the BRIC stock markets in Fig. 3 and 4 is only the magnitude of the responses.

Thus, the dynamic linkages of individual BRIC markets to overall BRIC are evident in the long-run, but there is very little evidence about the market-to-market dynamic linkages especially in the short-run (i.e., 30 periods).

Table-7. VDA Results

Period	S.E.	SENSEX	SHCO	BOVESPA	RTS
Variance Decomposition of SENSEX					
1	204.7808	100.0000	0.000000	0.000000	0.000000
5	450.7695	99.91067	0.000794	0.088312	0.000220
10	626.3548	99.59885	0.004035	0.397772	0.001345
30	1029.099	96.84628	0.049418	3.077680	0.026624
90	1654.770	85.95931	0.593060	12.90254	0.545096
180	2228.650	76.34150	2.461820	18.54008	2.656605
365	2985.912	67.36258	7.920955	17.05283	7.663637
1825	4284.128	52.14925	27.93821	10.24876	9.663780
3650	4337.431	51.13319	29.25198	10.03317	9.581661
Variance Decomposition of SHCO					
1	204.7808	6.705989	93.29401	0.000000	0.000000
5	105.9647	6.746062	93.25278	0.000413	0.000747
10	149.3612	6.791197	93.20350	0.001746	0.003554
30	1029.099	6.924219	93.02916	0.011089	0.035528
90	1654.770	7.025201	92.63165	0.027817	0.315327
180	2228.650	6.827890	92.04256	0.020246	1.109307
365	2985.912	6.257447	90.49007	0.042997	3.209483
1825	4284.128	5.136878	85.68947	0.324567	8.849080
3650	4337.431	5.107857	85.51908	0.338367	9.034700
Variance Decomposition of BOVESPA					
1	204.7808	8.709819	0.363447	90.92673	0.000000
5	1783.756	9.738818	0.427418	89.82565	0.008109
10	2468.090	11.06403	0.515548	88.38229	0.038129
30	1029.099	16.53060	0.949966	82.16040	0.359034
90	1654.770	30.29146	2.765041	64.44142	2.502080
180	2228.650	40.49814	5.953453	47.32644	6.221965
365	2985.912	45.24933	12.18430	31.59385	10.97252
1825	4284.128	40.49285	31.06641	17.66103	10.77971
3650	4337.431	39.79371	32.22255	17.28941	10.69434
Variance Decomposition of RTS					
1	204.7808	40.52792	32.19350	16.67484	10.60375
5	58.04012	15.50631	0.790251	9.187921	74.71552
10	81.57183	15.03976	0.845134	10.11177	74.00334
30	1029.099	40.52592	32.19119	16.67462	10.60827
90	1654.770	40.52236	32.18762	16.67563	10.61439
180	2228.650	40.51927	32.18484	16.67751	10.61838
365	2985.912	40.51727	32.18429	16.67898	10.61946
1825	4284.128	40.51268	32.19488	16.67592	10.61652
3650	4337.431	40.51210	32.19575	16.67565	10.61650

Table 7 has shown the VDA results of BRIC stock markets. In case of the Indian stock market (i.e., the BSE SENSEX), Table 7 decomposes the variance of indices returns at and reveals that by and large, the return at the exchange is composed by the previous days' levels/returns at the same. Throughout the study period this at large has been found in Indian case. However, it is evident that the SHCO, BOVESPA, and RTS indices returns leave a visible impact on the returns of the BSE

SENSEX Index, particularly as and when time lapses. This is in conformity with the short-run results as produced by the Granger's causality test results in case with the Brazilian stock market and not with the SHCO and RTS indices.

VDA separates the variation in one market into component shocks in the other markets. Overall, the VDA results in Table 7 show that among the BRIC stock markets, Indian (with less than 1% of its forecast error variance explained by other markets upto period 10), Chinese (with less than 7%), and Brazilian (with less than 12%) markets are not very responsive to BRIC foreign shocks. On the contrary, Russian stock market is very sensitive to foreign shocks (i.e., over 25% of the variance explained by BRIC foreign markets).

It is also observed from Table 7 that the Indian stock market (as represented by the BSE SENSEX Index) has a visible impact on the Russian (more than 15%), Brazilian (more than 8%), and Chinese (more than 6%) from the very first period to period 10 (i.e., in the very short-run) under this study. In the long-run (i.e., 5 years or more here) it is found that the BSE SENSEX Index's forecast error variance are strongly responsive to the Chinese, Brazilian, and Russian stock markets in that order. It has also been found from Table 8 that India is influencing the forecast error of returns of Brazilian and Russian (more than 40% in each case) in the long-run which is a clear evidence of India's dominance among the BRIC countries.

In case of the Chinese stock market (i.e., the Shanghai Composite Index), Table 7 has shown that the return at the exchange is composed by the exchange itself for the initial periods. However, the BSE SENSEX Index returns also show a visible impact on the Chinese stock market from the very 1st period. Though the BOVESPA Index returns do not have any significant impact on the SHCO, but with the passage of time, it is observed that the Russian stock market is showing a visible impact on it. However, the findings are not in conformity with the Granger's causality test, which has shown that none of the other stock exchanges under this study granger causes the Chinese stock market.

In case of the Brazilian stock exchange Table 7 shows that the returns from the BOVESPA Index are composed by the exchange itself for the periods up to 90. Also, the BSE SENSEX Index and the Chinese stock market put a very large and visible impact on the BOVESPA with the passage of time more than its own Index returns, but the RTS Index has less impact in comparison to other BRIC markets in the long-run. These results are in line with the Granger causality test results for the Brazilian stock market (i.e., the BOVESPA Index).

The VDA results of the Russian stock market (represented by the RTS Index) have shown a very unique case. It is observed that the RTS Index returns are largely impacted by the Indian, Chinese, and Brazilian stock indices returns in that order throughout the study period. However, the Granger causality test does not indicate similar results in the short-run for the RTS Index returns, except for the BOVESPA Index.

After an in-depth study to find short-run relationships and dynamic linkages of BRIC stock markets, this study reveals the long-run integration of in between these markets.

Here, one lag length has been selected on the basis of both AIC and SIC (see Table 5).

Under the JJ tests, test statistics are calculated allowing for an intercept and no trend term in the cointegrating equation (CE) and no intercept in VAR.

Table-8.1. JJ Cointegration Test Results
Likelihood Ratio (Trace) Test for Cointegrating Rank

Variable	Eigenvalue	Likelihood Ratio (LR)	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)
SENSEX	0.009053	36.22583	47.21	54.46	None
SHCO	0.003264	12.54432	29.68	35.65	At most 1
BOVESPA	0.000932	4.031214	15.41	20.04	At most 2
RTS	0.000616	1.604168	3.76	6.65	At most 3

*(**) denotes rejection of the hypothesis at 5% (1%) significance level.
L.R. rejects any cointegration at 5% significance level.

Table-8.2. JJ Cointegration Test Results
Max-Eigenvalue Test for Cointegrating Rank

Variable	Eigenvalue	Max-Eigen Statistic	5% Critical Value	1% Critical Value	Hypothesized No. of CE(s)
SENSEX	0.009053	23.68151	27.169	31.943	None
SHCO	0.003264	8.513106	20.778	25.521	At most 1
BOVESPA	0.000932	2.427046	14.036	17.936	At most 2
RTS	0.000616	1.604168	3.962	6.936	At most 3

*(**) denotes rejection of the hypothesis at 5% (1%) significance level.
Max-Eigenvalue rejects any cointegration at 5% significance level.

The results of the Johansen and Juselius's Trace test and Max-Eigenvalue test are shown in Tables 8.1 and 8.2. At the 5% significance level the Trace and maximum Eigenvalue tests suggest that the variables are not cointegrated at all. It indicates that there are no cointegration vectors in order to establish the long-run relationships among the BRIC stock markets. Thus, unlike results from earlier Fig. 1, Table 4, and above short-run tests, no long-run comovements have been found among these markets.

To make my study more reliable and authentic, I have also applied Engle and Granger (1987) cointegration test to find out whether there are any long-run equilibrium relationships in between BRIC indices. The ADF and PP tests have been applied on the residual series generated by regressing BSE SENSEX on other BRIC indices (taking one at a time) using one lag. Table 9 points out the results of the above test.

Table-9. ADF and PP Tests Results (with Intercept and no Trend) of Residual Series Post-Regression

ADF Tests			PP Tests		
Variables	Level	Conclusion	Variables	Level	Conclusion
SENSEX & SHCO	–1.148277	I(1)	SENSEX & SHCO	–1.168337	I(1)
SENSEX & BOVESPA	–4.184367	I(0)	SENSEX & BOVESPA	–4.615036	I(0)
SENSEX & RTS	–1.549167	I(1)	SENSEX & RTS	–1.559263	I(1)

Level - Critical value at 1% significance level is –3.4359, at 5% significance level is –2.8632 and at 10% significance level is –2.5677

The hypothesis which posits that the residual series is non-stationary is accepted in cases of SENSEX and SHCO, and SENSEX and RTS under both ADF and PP tests results. Hence, it can be inferred that the Indian stock market is not integrated with the markets of China and Russia. It implies that the Indian market does not have a long-run equilibrium relationship with them. However, in case of SENSEX and BOVESPA (of Brazil), it is found that the residual series is stationary based on both ADF and PP tests results. So, there exists a long-run integration (i.e., equilibrium relationship) in between the Indian and Brazilian stock markets. Thus, it is found that JJ, and Engle and Granger's tests are giving contradictory results under this study.

5. CONCLUSION

This study has tried to investigate the interrelationships (both in the short and long-run), interdependencies, integration, and dynamic linkages of the Indian stock market, i.e., the BSE SENSEX Index with other BRIC indices from China, Brazil, and Russia.

The Jarque-Bera test has pointed out non-normality of the indices data series. Thus, the ADF and PP tests are conducted. The results point out that the data is non-stationary at level, but integrated at order 1 [i.e., I(1)]. Based on these results, the JJ cointegration tests are undertaken. It is found that no long-run relationships exist in between the BRIC stock markets. However, there

exists a long-run integration (i.e., equilibrium relationship) in between the Indian and Brazilian stock markets according to the Engle and Granger's tests results. Correlation results have also found strong positive correlation for all BRIC markets. The short-run interrelationships and integration has been found in both directions for the Indian and Brazilian stock markets. This result has also been authenticated by the subsequent impulse response functions and VDA analysis results. Some other unidirectional short-run relationships have also been found in between SHCO to BOVESPA and BOVESPA to RTS indices.

The IRF has pointed out that in the short-run the shocks do have impact on the Indian stock market. The dynamic linkages have also been found in between BRIC markets in the long-run also. The VDA analysis results have also pointed out to the role of the BRIC markets on each others' movement. It is clearly evident that the Indian stock market has been taking the most dominant role in impacting the other BRIC stock markets more than others. Thus, it can be concluded that BRIC stock markets are the most favourable destination for global investors in the coming future and among the BRIC the Indian stock market has the dominance.

However, this study is not free from limitations. Natural logarithmic daily returns from the selected markets instead of closing indices value could give better and authentic results. Also, this study didn't take into consideration the impact of subprime crisis that caused havoc throughout the world during this study period. These limitations could be looked into in future studies.

Future researches should also take into consideration the role of other developed countries, like the US, UK, Germany, Japan, etc. or other developing regions like the ASEAN-5, etc. on the BRIC stock markets with the same data series.

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