BRIC and US Integration and Dynamic Linkages

An Empirical Study for International Diversification Strategy

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Abstract

This study aims at investigating the integration and dynamic linkages in between BRIC and the US stock markets both in the short and long-run with special reference to India. It has undertaken daily closing values of these indices from 1st January 1998 to 31st December 2012 and applied VAR, cointegration, and Granger causality tests to fulfill its objectives. Empirical results point out long and short-run relationships in between the Indian and Brazilian stock markets only. The strong impact of the Indian stock market on the Brazilian and Russian stock markets is also found. The interdependencies (mainly between 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 Chinese stock market has the dominance.

**Key Words:** BRIC and US stock markets; Integration; Dynamic linkages; ADF and PP tests; JJ cointegration tests; Engle-Granger cointegration test; Pairwise Granger causality tests; Impulse response functions; Variance decomposition analysis.
1. Introduction

One of the biggest challenges in the 21st Century financial markets including stock markets is the selection of the most profitable investment avenue and country for the global investor fraternity. Innovation and advancement in Information and Communication Technologies (ICTs), rapid pace of globalization around the world especially in the developing countries including Brazil, Russia, India, and China (BRIC), integration and dynamic linkages of global stock markets, and thereby the shivering impact (i.e., volatility spillovers) of financial crises and scams in all parts of the world have caused this challenge. One of the success mantra amidst these critical situations is the thorough understanding and accurate assessment of the impact of one international stock market over the other(s). Thus, empirical study like this to investigate the integration and dynamic linkages of international stock markets with different time-horizon is a must (refer Siddique, 2009). Also, the variables empirically examined as reasons behind the integration and dynamic interlinkages of the stock markets worldwide by various researchers, bilateral-trade and time-trend were found to be most significant (Johnson and Soenen, 2003; Mukherjee and Mishra, 2007; and Pretorius, 2002).

This paper analyzes such relationships of the Indian stock market with that of the other BRIC peers and the United States of America (USA). The reason behind selecting BRIC for this study is their already existing bilateral-trade relationships. For example, 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). 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). Selection of the USA is also undertaken on this ground as it is the second largest exporter (9.6% of total exports in 2010), and the largest importer (15% of total imports in 2010) to Brazil; the third largest exporter (5.6% of total exports in 2010) to Russia; the largest exporter (12.6% of total exports in 2010), and the fourth largest importer (5.7% of total imports in 2010) to India; and the largest exporter (18% of total exports in 2010), and the third largest importer (7.3% of total imports in 2010) to China.

Also, the economic potential of the BRIC countries is such that they could become among the four most dominant economies by the year 2050 (O’Neill, 2008). These countries encompass over 25% of the world’s land coverage and 40% of the world’s population and hold a combined Gross Domestic Product (GDP) (Purchasing Power Parity [PPP]) of 18.486 trillion dollars. Together, the four BRICs may account for 41% of the world’s market
capitalization by 2030 (Goldman Sachs, 2010). On almost every scale, they would be the largest entity on the world stage.

Thus, this study of stock market integration and dynamic interlinkages will have important implications for the global and Indian international investors as well the policy-makers. Global and Indian investors should track their markets of interest all over the world to understand the forces behind the integration of stock markets in order to realize the possible risks and returns of global diversification (Mukherjee, 2004). So, it is important to understand the US stock markets’ integration with the other emerging world super powers such as the BRIC countries, ASEAN nations or the developed markets such as the United Kingdom (UK), Japan, etc. Policy-makers need to understand the forces responsible in driving the stock market integration and such understanding will help in providing a better grasp over the global stock markets and the impact of those on their economies.

In the existing theoretical literature, financial market integration derives its root from the Capital Asset Pricing Model (CAPM) by Sharpe (1964) and Lintner (1965), and the Arbitrage Pricing Theory (APT) by Ross (1976). It is characterized by the law of one price (Cournot, 1927 and Marshall, 1930), and portfolio diversification with risky assets (Markowitz, 1952). It indicates that if risks command uniform price, then the correlation of financial asset prices and the linkage among international financial markets comes from the movement in the price of risks due to investors’ risk aversion. Thus, it can be derived that in case of interlinked stock markets with high correlations, the portfolio diversification benefits are wiped off. Therefore, the investigation and analysis of the relationships that the stock markets have facilitate all types of investors in reaching the most profitable investment decision and destinations. So, one should invest in markets which are not well interlinked to reap maximum profits.

Originally, the stock market integration studies generally had the objective to examine the diversification benefits gained by investing across international markets. Also these studies were based on various versions of asset pricing models like the above. However, most recent studies post-1997 Asian financial crisis (e.g., Aloui et al., 2011; An and Brown, 2010; Ayuso and Blanco, 1999; Bhar and Nikolova, 2009; Chittedi, 2009; Gupta, 2011; Koźluk, 2008; Shachmurove, 2006; Sheu and Liao, 2011; Wong, Agarwal and Du, 2005; etc.) worked mainly on the integration and dynamic linkages of the relevant international stock markets with the help of modern econometric techniques.

Thereby, this study aims at finding the short and long-run relationships and dynamic interlinkages in between the BRIC stock markets, and the US stock market. The differential importance, and impact or innovation of the US stock market on each of the above BRIC markets is also studied here. Additionally, this study will find which of the other four markets has the most influence and dynamic linkage on and with the Indian stock market. At the end,
based on empirical results this study will conclude by pointing out the most profitable diversification opportunity for the global investors in between the BRIC countries and the US.

This study uses graphical presentations, descriptive statistics results (to verify the nature and normality of the data series), correlation test results, Augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979; 1981) tests and Phillips-Perron (PP) (1988) tests (to find out the unit-roots if any), Johansen and Juselius’s (JJ) (1990) cointegration technique and Engle-Granger’s (1987) cointegration test, and Granger’s (1969) causality test. If there are more than two variables, Granger’s (1969) causality test may not give authentic results. So, I use Vector Autoregression (VAR) technique to detect causality under this study. Impulse Response Functions (IRFs) and Variance Decomposition Analysis (VDA) techniques are employed here to interpret the VAR model. The study period is taken from 1st January 1998 to 31st December 2012.

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 integration, and dynamic linkages in between BRIC and the US stock markets is undertaken 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

Financial integration ensures the law of one price to financial assets with the same risk (Adam et al., 2002). Dynamic linkages also point out the impact of shock/innovation in one national market to another. Thus, in perfectly integrated and dynamically interlinked markets, all assets with identical risk exposure also command identical expected returns (Campbell and Hamao, 1992). So, a high degree of integration between national stock markets minimizes the potential benefits from international portfolio diversification (Bessler and Yang, 2003).

The integration and dynamic linkages of international stock markets is a vastly-researched area. However, for the purpose of this study I am only undertaking the relevant BRIC and the US stock markets’ integration and dynamic linkages literature.

Earlier studies by Ripley (1973), Lessard (1976), and Hilliard (1979) found low correlations between national stock markets, supporting the benefits of international portfolio diversification. Post-October 1987 international market crash people realized that various national equity markets are closely connected as the developed markets like the US stock market exert a strong influence on other markets.
Lee and Kim (1994) investigated the effect of the October 1987 crash and found that national stock markets became more interrelated after the crash, and concluded that the comovements among these markets were stronger when the US stock market is more volatile.

Ayuso and Blanco (1999) showed that during the 1990’s linkages between national stock exchanges seem to have increased. Not only as the weight of foreign assets in agents’ portfolio increased, but also have the correlation between stock indices and the ability of each market return to explain the behaviour of other markets’ returns.

Similar to the tendency of the rising integration of the world markets (Bracker et al., 1999), the Brazilian stock market is also found to be more integrated in recent years than in the past (see Aktan et al., 2009; Rivas et al., 2008; etc.). However, lack of integrating relationship is found in the studies that used cointegrating techniques (e.g., Ozdemir et al., 2009; Tabak and Lima, 2002; etc.).

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. However, recently Chow et al. (2011) observed rising integration of the Chinese and world stock markets, measured in terms of comovements of Shanghai and New York Stock exchange prices.

Rao and Naik (1990) applied the Cross-Spectral analysis and found that the Indian stock index, the gains estimates from either the US or the Japan indices are not dependent, and hence they concluded that the relationship of Indian market with international markets is poor reflecting the institutional fact that the Indian economy has been characterized by heavy controls throughout the entire seventies with liberalization measures initiated only in the late eighties.

Wong, Agarwal and Du (2005) empirically investigated the long-run equilibrium relationship and short-run dynamic linkage between the Indian stock market and the stock markets in major developed countries (the US, UK, and Japan) post-1990 by examining the Granger causality relationship and the pairwise, multiple, and fractional cointegrations. They concluded that the Indian stock market is integrated with mature markets and sensitive to the dynamics in these markets in the long-run. In the short-run, both the US and Japan Granger causes the Indian stock market, but not vice versa. Additionally, they found that the Indian stock index and the mature stock indices form fractionally cointegrated relationship in the long-run with a common fractional, non-stationary component, and that the Johansen method is the best to reveal their cointegration relationship. Another study on comovement among selected stock markets conducted by Modi et al. (2010) found that the correlation of BSE (India) with BVSP
(Brazil), MXX (Mexico), FTSE100 (UK), DJIA and NASDAQ (USA) is low. Therefore, these combinations provide attractive portfolio diversification opportunities for Indian investors.

**Shachmurove (2006)** analyzed the dynamic interrelationships among the stock exchanges of the US and 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 US stock market. This result seems to encourage a larger extent of US purchases and activities in the Chinese stock markets in order to improve diversification.

**Chittedi (2009)** examined the integration of the BRIC stock markets 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. As expected, unit-root tests for the overall period indicated that stock prices are non-stationary, but stock returns are generally stationary for all indexes. 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 the BRIC stock markets with the exception of China provide attractive portfolio diversification opportunities for global investors.

**Aloui et. al (2011)** evaluated on the comovements between the BRIC markets and the US during the period of the global financial crisis indicated that dependency on the US is higher and more persistent to Brazil-Russia than for China-India. In their study, the author paired Brazil and Russia - countries which are highly dependent on commodity prices and China-India whose economic growth is largely influenced by finished-products export-price level. The authors utilized copula functions in their study which also revealed the high level of dependence persistence for all market pairs during both bullish and bearish markets.

**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. Popular Indices of BRIC countries have taken as the proxy of their Stock markets. He had taken IBOV, RTS Index, S&P Nifty, SCI (Shanghai Composite index) as the proxy for the stock market of the BRIC countries respectively. Several statistical tests have been applied in order to study the behaviour and dynamics of time series of BRIC indices. The period for the study was taken from January 2008 to November 2011 using the daily closing indices. Kurtosis, Skewness, and Jarque-Bera test were undertaken to investigate the normal distribution of time series and it is found them non-normally distributed. Correlation matrix was computed which shows the positive correlation among all the proxy indices of the BRIC countries. Through unit-root tests, it was established that all these time series indices are stationary at the level form itself. Granger Causality test was done to find out the causal relationship between the time series of the BRIC indices. It was 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 gave statistic that the Chinese economy have the bidirectional causality with India and Russia. Thus the 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 study used both the linear Engle–Granger cointegration test and the non-linear Enders–Siklos cointegration test for comparative analysis, and it expanded the consistent momentum threshold autoregressive model and the threshold error correction model by time-varying approaches for dynamic analysis. The evidence demonstrated that both long-run time-varying non-linear cointegration relationships and short-run time-varying Granger causality relationships exist between the stock markets of US–Brazil, US–India, US–Russia, and US–China (USBRIC). Furthermore, these relationships were altered in the short-run during 2007–2008, when the subprime mortgage financial crisis in the US occurred. The empirical results also 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.

Reddy and Wadhwa (2012) made an attempt to understand the integration of BRIC emerging markets which are gaining prominence in the investment community with the USA. The data for the study is considered from 1st April
2000 to 31st January 2010. The results indicated that there is a varying degree of cointegration among the BRIC and US nations which is mainly due to the trade relations between these countries.

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 have been conflicting results regarding the nature of dynamic interdependence between developed and/or emerging markets.

Thus, it is quite clear from the above literature review that although studies on stock market integration and dynamic linkages are in abundant numbers, however results vary according to variable specification, research methodology adopted, participating countries or regions, and the period of such study. 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 weaknesses in detail. Also, the impact of the USA on the BRIC stock markets, and the same of other BRIC countries on the Indian stock market for the whole study period and its dynamic linkages with them have also been thoroughly examined.

3. Data and Methodology

In this study, I have used daily closing prices from 1st January 1998 to 31st December 2012 (3,934 observations in total for all the BRIC and USA 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]), National Stock Exchange (S&P CNX Nifty [i.e., NIFTY here]), and Shanghai Stock Exchange (SSE Composite Index [i.e., SHCO here]) respectively for representing the selected countries. All these indices are the main bellwether of respective economies, and premier benchmark indices to measure the fast growing stock markets of these countries. The data has been collected from www.econstat.com, www.nse.com, and www.rts.ru. Also, in this study I have adopted the method of Occam’s razor by simply filling in with the price of previous day (Hirayama and Tsutsui, 1998; Jeon and Furstenberg, 1990; Majid et al., 2009; etc.) when respective Index prices are not available due to different stock exchange holidays. The justification is since no fresh information publicized during holidays, the information of previous day would be carried over to the succeeding day.

The two most important criteria to examine when one deals with indices data series is that of normality and stationarity. In this study, I have used the Jarque-Bera test (JB) (Gujarati, 2004) to test whether stock indices of the BRIC and USA individually follow the normal probability distribution pattern. The JB test of normality is
asymptotic or a large–sample test. This test computes the skewness and kurtosis measures and uses the following test statistics:

$$JB= n \left[ S^2/6 + (K-3)^2/24 \right]$$  \hspace{1cm} (1)

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

It is also necessary to test the order of integration of each variable in the model to establish whether it is non-stationary and how many times the variable needs to be differenced so that a stationary data series can be recovered. The ADF (Dickey and Fuller 1979; 1981) and PP (1988) unit-root tests are employed in this study to avoid the problem of spurious regressions.

In this study, I have used the following equation to test for unit-roots through ADF tests:

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

Where, \( \alpha_0 \) is a constant, \( \lambda \) 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 \( y_t \), \( \Delta y_{t-i} \) are changes in lagged values, and \( u_t \) is white noise.

Thus, I have tested the null hypothesis of \( \lambda = 0 \) against the alternative hypothesis of \( \lambda < 0 \). The null hypothesis of non-stationarity is rejected if \( \lambda \) is negative and significantly different from zero.

In this study, I have used the following equation to test for unit-roots through PP tests which is the AR(1) process:

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

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 and the US stock markets. However, Leong and Felmingham (2001) 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’s (1969) pairwise causality test.

Granger’s (1969) pairwise causality test establishes short-run relationships between the selected indices. It is a bivariate analysis and involves estimates \( X(Y \rightarrow X) \) and \( Y(X \rightarrow Y) \) by using following pair of regressions:
\[ Y_t = \beta_0 + \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{i=1}^{n} \beta_i Y_{t-i} + \epsilon_t \]  \hspace{1cm} (4) \\
\[ X_t = \lambda_0 + \sum_{i=1}^{n} \delta_i Y_{t-i} + \sum_{i=1}^{n} \lambda_i X_{t-i} + \epsilon_2_t \]  \hspace{1cm} (5)

Where, the null hypothesis is \( \alpha_i = \delta_i = 0 \). If the \( \alpha_i \) is statistically significant but \( \delta_i \) 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 return do not yield a statistically significant relationship, then it can be stated that such return does not Granger cause the other index return. Thus, the F-test value is the standard one in this regard.

Here, I have used a VAR model to analyse the degree to which a change in one country’s stock price series exerts an influence on a change in other countries’ stock price series, and the time path of the latter. Hence, the major difference between these interdependencies, and the earlier comovement among BRIC and the USA stock price series, lies in the fact that this VAR test examines the dynamic structure of stock price developments. Thus, this study finds the effect of a shock (through an innovation or news) in one stock market on the others.

In this study, I have applied the VDA to quantify the extent upto which the four BRIC stock market indices are influenced by each other, and also how the US market shock is impacting the BRIC stock markets. While IRF traces the effects of a shock to one endogenous variable on to the other variables in the VAR, VDA separates the variation in an endogenous variable into the component shocks to the VAR. Thus, the VDA provides information about the relative importance of each random innovation in affecting the variables in the VAR.

I have also undertaken the IRF analysis to obtain additional insights into the transmitting mechanism of the stock market movements in the BRIC and US stock markets to the Indian stock market. The pattern of dynamic responses of each of the five stock markets to a shock, i.e., positive residuals of one standard deviation unit in the corresponding stock market, have been 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. I have used two cointegration techniques, namely, Johansen and Juselius’s (1990), and Engle-Granger’s (1987) cointegration tests to examine the existence of long-run integration (if any) between above markets. Most of the previous studies have also used the above mentioned techniques (Arshanapalli et al., 1995; Click and Plummer, 2005; Wong et al., 2005; Bose and Mukherjee, 2006; Janor et al., 2007).

If it is found that all stock market indices under this study is I(1), then cointegration (i.e., long-run) relationships between them can be tested. In this study, the Johansen and Juselius’s (1990) Trace and Maximum Eigenvalue tests have been employed to test the long-run relationships among the stock market indices of the BRIC and the USA. 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 this study, to fulfill the above objectives the following VECM-specific equation is used:

$$\Delta y_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + \epsilon_t$$

(6)

Where,

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j$$

and

$$\Pi = -I + \sum_{i=1}^{p} A_i$$

(7)

Here, the Trace and Maximum Eigenvalue tests have been used to find the number of cointegrating vectors. The equations for these tests are as follows:

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

(8)

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

(9)

Where, $T$ is the sample size and $\hat{\lambda}_i$ is the $i$th 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 will 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 selection (Enders and Todd, 2004). In this study, I have employed Akaike Information Criteria (AIC) and Schwarz Information Criterion (SIC) to select the appropriate lag length.

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

$$Y_t = \beta_1 + \beta_2 X_t + \mu_t$$

(10)

Now, if the residual series of this regression is subject to unit root test and the results show that it is stationary i.e. [I(0)], it means that $X_t$ and $Y_t$ are co-integrated. Economically speaking, the two variables are cointegrated if they have a long-run or equilibrium relationship between them. 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 series. To perform the cointegration analysis, S&P CNX NIFTY 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. 2 and 3), and descriptive statistics results to find out the normality of the indices data series.

‘Insert Figure 2 and 3 here’
Figure 2 and 3 has pointed out that the BRIC and US indices are very volatile in their movement. Also, it is evident that there is a clear case of comovements in the long and short-run for these stock markets.

‘Insert Table 1 here’
Table 1 presents the summary statistics of the indices under this study. The average daily indices value for all BRIC and US indices during the study period with a high standard deviation imply highly volatile stock markets. Higher Skewness value of the above variables during the study period indicates a deviation from normal distribution of the data series, and also volatility in them. The value of kurtosis has pointed out that SHCO and NASDAQ 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. The Test value indicates non-normality of the stock indices data series.
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.

‘Insert Table 2 here’
The results in Table 2 indicate the presence of a unit-root in the levels of all indices. Thus, the null hypothesis of a unit-root cannot be rejected. However, there is no evidence to support the presence of a unit-root in first differences of the BRIC and the US stock market indices. Hence, changes in stock prices are stationary. In other words, all these 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.

‘Insert Table 3 here’
Table 3 has pointed out that all the BRIC stock markets are positively correlated with a high level of significance. Especially, the S&P CNX NIFTY 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. However, no significant positive correlation is found in between the BRIC indices and the NASDAQ.

This study has applied Granger causality test of Granger (1969) with 1 lag (see Table 4).

Test results are shown in Table 5. It shows no short-run causal relationship in between NIFTY and SHCO, and also in between NIFTY and RTS. The US stock market also has no relationship with the NIFTY in the short-run. However, the Indian stock market represented by the S&P CNX NIFTY Index under this study granger causes the Brazilian stock market, i.e., the BOVESPA Index in the short-run and not the other way round. BOVESPA in turn has a short-run causal relationship with the Russian stock market. No other BRIC stock markets are found to have any other short-run relationships in between them. Also, the US stock market has no unidirectional or bi-directional causal relationships with the BRIC indices. Overall, this study has found two unidirectional and no bi-directional Granger causality effect in between the BRIC and the US stock markets.

The pattern of dynamic responses of each of the four BRIC and the US stock markets to a shock, i.e., positive residuals of one standard deviation unit in the US stock market, has been examined first. Fig. 4 has presented the results.

It is worth mentioning here 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 this study, the causal ordering of the variables is BRIC first and then the US stock market indices in the order of BOVESPA, RTS, NIFTY, SHCO, and NASDAQ. Figure 5 and 6 provide plots of the time paths of the impulse responses for these four BRIC stock markets to a market shock (i.e., in the US market) during the study period (Figure 5), and also impulse responses of NIFTY to the corresponding market shock in BRIC and US markets (Figure 6) at the finest time scale (d1). In Figure 5, the solid line plots the point estimates of the impulse responses of the BRIC and US stock market indices to standard deviation shocks of the NASDAQ. In Figure 6, the solid line plots the point estimates of the impulse responses of the Indian stock market index, i.e., the S&P CNX NIFTY to standard deviation shocks of the BRIC and US stock indices. The dotted lines in both the figures are the two standard deviation bands around the points estimates.
The dynamic linkages of the BOVESPA, RTS, NIFTY, SHCO, and NASDAQ to BRIC and US stock indices are quite clear from the above figures. A positive one standard deviation shock to the BRIC and US 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, RTS and NASDAQ have also shown similar types of dynamic linkages in this study. Except China, all other BRIC stock markets are also showing a negative impact on shocks of the US stock market. Also, except RTS in the short-run all other stock markets under this study are also having a positive impact on the Indian stock market.

Thus, the dynamic linkages of individual BRIC markets to overall BRIC and the US stock market are evident both in the short and long-run.

‘Insert Table 6 here’

In this study, Table 6 shows the VDA results of BRIC and US stock markets. In case of the Indian stock market (i.e., the S&P CNX NIFTY), Table 6 decomposes the variance of indices returns at and reveals that by and large, the return at the market is composed by the previous days’ levels/returns at the same in the short-run (i.e., upto 90 periods). However, it is evident that the BOVESPA, SHCO, and RTS indices returns leave a visible impact on the returns of the S&P CNX NIFTY Index with the passage of time (i.e., post-90 periods). The US stock market has very little impact on it especially upto 1-year mark. This is in conformity with the short-run results as produced by the Granger’s causality test results (see Table 5) 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 8 has also shown that among the BRIC stock markets, Brazilian (with less than 1% of its forecast error variance explained by other markets upto period 10), and Chinese (with less than 8%) markets are not very responsive to BRIC and US foreign shocks in the very short-run. On the contrary, Russian stock market is very sensitive to foreign shocks (i.e., over 98% of the variance explained by foreign markets). It is also observed from Table 8 that the Indian stock market (as represented by the S&P CNX NIFTY Index) has a visible impact on the Russian (more than 12%) 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 S&P CNX NIFTY Index’s forecast error variance are strongly responsive to the Brazilian, Chinese, and US stock markets in that order. It is also found from Table 8 that India is influencing the forecast error of returns of Brazilian (more than 13%), Russian (more than 12%), and especially the US (more than 25%) in the long-run which is a clear evidence of India’s role among the BRIC countries.
In case of the Chinese stock market (i.e., the Shanghai Composite Index), Table 8 shows that the return at the market is composed by the exchange itself for the initial periods. However, the NIFTY, RTS, and BOVESPA indices returns show a prominent impact on the Chinese stock market from the very 1st period. Though the NASDAQ Index returns do not have any significant impact on the SHCO initially, but with the passage of time, it is observed that along with the Brazilian, and Russian stock markets it is also showing a visible impact on SHCO. However, these findings are not in conformity with the Granger’s causality test, which has shown that none of the other stock markets under this study granger causes the Chinese stock market. However, the Chinese stock market with more than 23%, 26%, and 21% forecast error variance for the Brazilian, Russian, and Indian stock markets in the long-run has clearly been the dominant force among the BRIC.

In case of the Brazilian stock exchange Table 8 shows that the returns from the BOVESPA Index are composed by the exchange itself for the periods upto 90. Also, the Chinese, and Indian stock markets put a very large and visible impact on the BOVESPA with the passage of time, but not more than its own Index returns. The RTS, and NASDAQ indices however has very little impact in comparison to the above two 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 Brazilian, Chinese, and Indian stock indices returns in that order throughout the study period. The US has however very little impact. The Granger causality test does not indicate similar results in the short-run for the RTS Index returns, except for the NASDAQ Index.

In case of the US stock market, it is found from Table 6 that the Brazilian stock market has huge impact in the short-run from the initial period. All other BRIC markets have little impact on it. However, with the passage of time, S&P CNX NIFTY’s forecast error variance become more significant along with BOVESPA, SHCO, and RTS.

Thus, it is clear from the above discussion that the Chinese stock market has the most visible impact on other BRIC markets over the period of study.

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.

In multivariate cointegration analysis using JJ technique, the first step is the appropriate lag selection for the variables. The AIC (Maddala and Kim, 2000) and SIC are widely used in the time series analysis to determine appreciative length of the distributed lag. In this study, this criterion is used to determine the lag length - the smaller the value of the information criteria, the ‘better’ the model is. Thus, one lag length has been selected equal in this study on the basis of both AIC and SIC (see Table 4).
Under JJ tests, test statistics are calculated allowing for an intercept and no trend term in the cointegrating equation (CE) and no intercept in VAR.

‘Insert Table 7.1 and 7.2 here’

The results of the Johansen and Juselius’s Trace test and Max-Eigenvalue test are shown in Tables 6.1 and 6.2 respectively. At the 1% significance level the Trace and maximum Eigenvalue tests suggest that the variables are not cointegrated at all. However, at 5% significance level Max-Eigenvalue test indicates existence of at least one cointegrating relationship (i.e., one cointegration vector). Thus, the long-run relationships among the BRIC and the US stock markets are only established in one pair of the markets. However, unlike results from earlier Fig. 2, Table 3, and the above short-run tests, only one long-run integration relationship has been found among these markets.

To make my study more reliable and authentic, I have also applied Engle and Granger’s (1987) cointegration test to find out whether there are any long-run equilibrium relationships in between BRIC and US indices. The ADF and PP tests have been applied on the residual series generated by regressing S&P CNX NIFTY on other BRIC and US indices (taking one at a time) using one lag. Table 8 points out the results of the above tests.

‘Insert Table 8 here’

The hypothesis which posits that the residual series is non-stationary is accepted in most cases, i.e., NIFTY and RTS, NIFTY and SHCO, and NIFTY and NASDAQ under both ADF and PP tests results. Hence, it can be inferred that the Indian stock market is not integrated with the markets of Russia, China, and the US. It implies that the Indian market does not have a long-run equilibrium relationship with them. However, in case of NIFTY 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-term integration (i.e., equilibrium relationship) in between the Indian and Brazilian stock markets. This is in line with the earlier JJ tests results of one-pair cointegration relationship in between BRIC and US markets. This, therefore, proves the robustness of the findings under this study.

5. Conclusion:

This study has investigated the integration, and dynamic linkages of the BRIC stock market with the US market with special reference to India.

The Jarque-Bera test has pointed out non-normality of the indices data series. Thus, the ADF and PP tests are conducted. These results point out that the data is non-stationary at level, but integrated at order 1 [i.e., I(1)]. Based on the results, the JJ cointegration tests are undertaken. It is found that only one long-run relationship exists in
between the BRIC and US stock markets. Engle-Granger’s test further points out that a long-term equilibrium relationship does exist in between the Indian and Brazilian stock markets.

These results are mostly in contradiction with the earlier results from the studies of Chittedi (2009), Reddy and Wadhwa (2012), etc., but in line with An and Brown (2010) [except China]. However, the correlation results have found strong positive correlation in between all BRIC markets. The short-run interrelationships and integration has been found in one direction for the Indian from the Brazilian stock market. This result is authenticated by the subsequent impulse response functions and VDA analysis results. Another unidirectional short-run relationship is found in between BOVESPA to RTS. No other unidirectional or bi-directional granger causality relationship is found in between the BRIC and US indices in the short-run.

The IRF points 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. There it is clearly evident that the Chinese 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 Chinese stock market is the most profitable portfolio diversification opportunity for them.

However, this study is not free from limitations. It didn’t take into consideration the impact of subprime crisis that caused havoc throughout the world during this study period.

Future studies should also take into consideration the role of other developed countries, like the UK, Germany, Japan, etc. or other developing regions like the ASEAN-5, etc. on the BRIC stock markets with the same data series. Also, macroeconomic analysis should be included in these kinds of studies to make the results more authentic and reliable.
References


Ayuso, J and Blanco, R. (1999). Has financial market integration has increased during the nineties? *Ban code Espana service de estudios, document de trabajon 9923*.


Figure 1 Ten largest economies in the world in 2050, measured in GDP
(billions of 2006 USD)

Source: Goldman Sachs

Figure 2 BRIC and US Indices Line Graph (Single Scale)
Figure 3 BRIC and US Indices Line Graph (Dual Scale [Crossing])

Figure 4 Response of BRIC and USA to One S.D. Innovations

Response of BOVESPA to One S.D. Innovations

Response of RTS to One S.D. Innovations

Response of NIFTY to One S.D. Innovations

Response of SHCO to One S.D. Innovations

Response of NASDAQ to One S.D. Innovations
Figure 5 Response to One S.D. Innovations ± 2 S.E.

![Graphs showing response of different indices to NASDAQ innovations](image1)

Figure 6 Response to One S.D. Innovations ± 2 S.E.

![Graphs showing response of different indices to NIFTY innovations](image2)
<table>
<thead>
<tr>
<th>Particulars</th>
<th>BOVESPA</th>
<th>RTS</th>
<th>NIFTY</th>
<th>SHCO</th>
<th>NASDAQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>34199.53</td>
<td>922.9956</td>
<td>2889.768</td>
<td>2099.981</td>
<td>2292.485</td>
</tr>
<tr>
<td>Median</td>
<td>26633.00</td>
<td>674.4800</td>
<td>2183.850</td>
<td>1813.500</td>
<td>2212.100</td>
</tr>
<tr>
<td>Maximum</td>
<td>73517.00</td>
<td>2487.920</td>
<td>6312.450</td>
<td>6092.060</td>
<td>5048.620</td>
</tr>
<tr>
<td>Minimum</td>
<td>4761.000</td>
<td>38.53000</td>
<td>808.7000</td>
<td>1011.500</td>
<td>1114.110</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>21595.03</td>
<td>686.7887</td>
<td>1776.838</td>
<td>927.8803</td>
<td>617.6855</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.335444</td>
<td>0.375548</td>
<td>0.385621</td>
<td>1.595793</td>
<td>1.148620</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>1.530453</td>
<td>1.728040</td>
<td>1.538728</td>
<td>5.875631</td>
<td>5.242026</td>
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<tr>
<td>Jarque-Bera</td>
<td>425.4829</td>
<td>355.7612</td>
<td>3009.012</td>
<td>1679.980</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Descriptive Statistics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Level</th>
<th>1st Difference</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOVESPA</td>
<td>–0.968375</td>
<td>–45.39170</td>
<td>I(1)</td>
</tr>
<tr>
<td>RTS</td>
<td>–1.104124</td>
<td>–41.50566</td>
<td>I(1)</td>
</tr>
<tr>
<td>NIFTY</td>
<td>–0.491818</td>
<td>–42.91005</td>
<td>I(1)</td>
</tr>
<tr>
<td>SHCO</td>
<td>–1.540814</td>
<td>–45.70728</td>
<td>I(1)</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>–2.129369</td>
<td>–45.24100</td>
<td>I(1)</td>
</tr>
</tbody>
</table>

Table 2: ADF and PP Tests Results (with Intercept and no Trend)

<table>
<thead>
<tr>
<th>Lag</th>
<th>AIC</th>
<th>SIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>–108722.70</td>
<td>–108722.70</td>
</tr>
<tr>
<td>2</td>
<td>–108409.60</td>
<td>–108409.50</td>
</tr>
<tr>
<td>3</td>
<td>–108332.90</td>
<td>–108332.90</td>
</tr>
<tr>
<td>4</td>
<td>–108258.80</td>
<td>–108258.80</td>
</tr>
</tbody>
</table>

Table 4: Lag Length Selection
Null Hypothesis:  
Observations | F-Statistic | Probability
--- | --- | ---
RTS does not Granger Cause BOVESPA | 3912 | 0.03914 | 0.84318
BOVESPA does not Granger Cause RTS | 3912 | 7.11519 | 0.00767
NIFTY does not Granger Cause BOVESPA | 3912 | 6.45922 | 0.01108
BOVESPA does not Granger Cause NIFTY | 24.6545 | 0.22053 | 7.2E-07
SHCO does not Granger Cause BOVESPA | 3912 | 1.50137 | 0.60069
BOVESPA does not Granger Cause SHCO | 3912 | 0.27400 | 0.60069
NASDAQ does not Granger Cause BOVESPA | 3912 | 1.14960 | 0.28370
BOVESPA does not Granger Cause NASDAQ | 3912 | 0.05043 | 0.82233
NIFTY does not Granger Cause RTS | 3912 | 1.77761 | 0.18252
RTS does not Granger Cause NIFTY | 3912 | 0.49178 | 0.48318
SHCO does not Granger Cause RTS | 3912 | 0.46542 | 0.49514
RTS does not Granger Cause SHCO | 3912 | 0.91025 | 0.34011
NASDAQ does not Granger Cause RTS | 3912 | 0.10355 | 0.74763
RTS does not Granger Cause NASDAQ | 3912 | 0.00061 | 0.98028
SHCO does not Granger Cause NIFTY | 3912 | 0.14457 | 0.70380
NIFTY does not Granger Cause SHCO | 3912 | 0.14630 | 0.70212
NASDAQ does not Granger Cause NIFTY | 3912 | 0.00593 | 0.93861
NIFTY does not Granger Cause NASDAQ | 3912 | 0.48880 | 0.48450
NASDAQ does not Granger Cause SHCO | 3912 | 1.34248 | 0.24667
SHCO does not Granger Cause NASDAQ | 3912 | 0.11012 | 0.74003

Table 5: Pairwise Granger Causality Tests Results

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>BOVESPA</th>
<th>RTS</th>
<th>NIFTY</th>
<th>SHCO</th>
<th>NASDAQ</th>
</tr>
</thead>
</table>

Variance Decomposition of BOVESPA

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>BOVESPA</th>
<th>RTS</th>
<th>NIFTY</th>
<th>SHCO</th>
<th>NASDAQ</th>
</tr>
</thead>
</table>

Variance Decomposition of RTS

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>BOVESPA</th>
<th>RTS</th>
<th>NIFTY</th>
<th>SHCO</th>
<th>NASDAQ</th>
</tr>
</thead>
</table>

Variance Decomposition of NIFTY

<table>
<thead>
<tr>
<th>Period</th>
<th>S.E.</th>
<th>BOVESPA</th>
<th>RTS</th>
<th>NIFTY</th>
<th>SHCO</th>
<th>NASDAQ</th>
</tr>
</thead>
</table>
### Table 6: VDA Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eigenvalue</th>
<th>Likelihood Ratio (LR)</th>
<th>5% Critical Value</th>
<th>1% Critical Value</th>
<th>Hypothesized No. of CE(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOVESPA</td>
<td>0.009683</td>
<td>58.12105</td>
<td>68.52</td>
<td>76.07</td>
<td>None</td>
</tr>
<tr>
<td>RTS</td>
<td>0.002569</td>
<td>20.06827</td>
<td>47.21</td>
<td>54.46</td>
<td>At most 1</td>
</tr>
<tr>
<td>NIFTY</td>
<td>0.001593</td>
<td>10.00731</td>
<td>29.68</td>
<td>35.65</td>
<td>At most 2</td>
</tr>
<tr>
<td>SHCO</td>
<td>0.000692</td>
<td>3.770338</td>
<td>15.41</td>
<td>20.04</td>
<td>At most 3</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>0.000271</td>
<td>1.061859</td>
<td>3.76</td>
<td>6.65</td>
<td>At most 4</td>
</tr>
</tbody>
</table>

*(**) denotes rejection of the hypothesis at 5% (1%) significance level.

L.R. rejects any cointegration at 5% significance level.

### Table 7.1: JJ Cointegration Test Results

Likelihood Ratio (Trace) Test for Cointegrating Rank

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eigenvalue</th>
<th>Max-Eigen Statistic</th>
<th>5% Critical Value</th>
<th>1% Critical Value</th>
<th>Hypothesized No. of CE(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOVESPA</td>
<td>0.009683</td>
<td>38.05278</td>
<td>33.178</td>
<td>38.341</td>
<td>None*</td>
</tr>
<tr>
<td>RTS</td>
<td>0.002569</td>
<td>10.06096</td>
<td>27.169</td>
<td>31.943</td>
<td>At most 1</td>
</tr>
<tr>
<td>NIFTY</td>
<td>0.001593</td>
<td>6.236972</td>
<td>20.778</td>
<td>25.521</td>
<td>At most 2</td>
</tr>
<tr>
<td>SHCO</td>
<td>0.000692</td>
<td>2.708479</td>
<td>14.036</td>
<td>17.936</td>
<td>At most 3</td>
</tr>
<tr>
<td>NASDAQ</td>
<td>0.000271</td>
<td>1.061859</td>
<td>3.962</td>
<td>6.936</td>
<td>At most 4</td>
</tr>
</tbody>
</table>

*(***) denotes rejection of the hypothesis at 5% (1%) significance level.

Max-Eigenvalue test indicates 1 co-integrating equation(s) at 5% significance level.

### Table 7.2: JJ Cointegration Test Results

Max-Eigenvalue Test for Cointegrating Rank
<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF Tests</th>
<th>PP Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
<td>Conclusion</td>
</tr>
<tr>
<td>NIFTY &amp; BOVESPA</td>
<td>–5.140877</td>
<td>I(0)</td>
</tr>
<tr>
<td>NIFTY &amp; RTS</td>
<td>–1.857104</td>
<td>I(1)</td>
</tr>
<tr>
<td>NIFTY &amp; SHCO</td>
<td>–0.765884</td>
<td>I(1)</td>
</tr>
<tr>
<td>NIFTY &amp; NASDAQ</td>
<td>–0.704977</td>
<td>I(1)</td>
</tr>
</tbody>
</table>

Level - Critical value at 1% significance level is –3.4351, at 5% significance level is –2.8628 and at 10% significance level is –2.5675

Table 8: ADF and PP Tests Results (with Intercept and no Trend) of Residual Series Post-Regression