Linkages among Selected Asian Stock Markets

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Abstract
We study the linkages among selected Asian stock markets using the time series data with the application of cointegration and causality tests. We find that our sample have very low association indicating potential gains from international diversifications. Our results show that Asian stock markets are interconnected in the long run and there exist a bidirectional as well as unidirectional causality among the Asian stock markets. Japan stock market occupies a highest proportion of shocks can be explained by its own innovation compared to other stock markets. It is also evident that shock to Srilanka and Bangladesh stock markets do not have any significant effect on any other stock markets.
Keywords: *Asian stock markets, causality test, cointegration test, correlation analysis, financial market integration.*

1. Introduction

Financial integration is a multidimensional method strongly linked to the development of financial markets. Economic theory recommends that financial integration brings with it important advantages, together with lower costs of trading financial assets, more varied investor portfolios and more stable consumption models, mainly when the level of economic activity varies extensively. The theory also recommends that nonexistence of constraints on capital mobility augments the level of efficiency with which global financial resources are distributed. The justification for this observation is that capital should mechanically flow from capital abundant to capital scarce countries.

The extent of integration of promising Asian stock markets has augmented over time, by this means proposing bigger risk of contagion from one home market to another market (Park, 2013; Tiwari et al., 2013). Various empirical researches (Hung and Cheung, 1995; Masih and Masih, 2001; Tiwari et al., 2013; Bhunia and Yaman, 2017) suggest that Asian stock markets are integrated and diversification opportunities in Asian stock markets are possible. Asian markets give precious opportunities for investors because the increase of the middle class in Asia has allowed consumption levels to get bigger and making various compartments of growth. The main reason for studying this research is that almost every researchers consider long-run financial data of Asian stock market including crises periods to estimate the linkages among the stock markets in this region, however, our study examines the dynamic linkages among Asian stock markets based on the percentage of change in share prices of seven Asian stock markets for the three years period starting from June 2014 and ending on September 2017. One of the main reasons of choosing this time period is that no big turmoil occurred to those stock markets in that time period. Also almost in all the countries taken under consideration, a stable government is running. In this paper, we want to check the impact and bonding of those share markets in a short time frame. The paper is prepared as follows. Section 2 reviews the literature on linkages among global stock markets. Section 3 explains the data and methodology. Section 4 presents the study's results and analysis and section 5 sums up our conclusions.

2. Literature review

A number of prior papers analyze the linkages among global stock markets. A few of these papers study the markets of a large group of countries around the globe. Other papers on linkages among stock markets of study countries in a definite region. Another group of studies focus on the linkages of the market of a single country with the markets of other countries. In what follows we review studies in these three groups of studies.

Gjerde and Sættem (1995), Francis and Leachman (1998) and Lee and Goh (2016) are examples of the first group of studies. Gjerde and Sættem (1995) examined the linkages among stock markets of ten countries based on time series data for the period between 1983 and 1994 using multivariate vector autoregressive model. The variance decompositions pointed out a strong degree of economic relations among stock markets and the US stock market had a significant shock on each stock market performance, whereas there was no considerable intercontinental shock from the European stock markets to the US and Japan equity markets. The impulse response functions demonstrated a speedy global transmission of stock market dealings. Francis and Leachman (1998) investigated the superexogeneity and vibrant linkages among global stock markets in terms of stock markets of UK, US, Japan and Germany based on monthly data for the period between January 1974 and August 1990 using cointegration and superexogeneity tests. They confirmed that markets holds one long-run symmetry path and each and every stock market were endogenous in the case of long-run association. These results concluded a credibility to the large class of anticipations based models that form the basis of financial modeling. In addition, the results showed that agents participating in these stock markets may prevent policies designed to influence global financial flows. Lee and Goh (2016) examined the linkages of the ASEAN-5 stock markets with the Hong Kong and U.S. markets for the period before and after the global financial crisis with the application of the multivariate GARCH model. They confirmed a weaker linkage among the markets and the response to bad market news has strengthened after the crisis. The U.S. stock market was the main cause to the mean spillover upshots. While the past instability and past impact spillovers upshots from the Hong Kong market were better, the ASEAN stock markets tend to respond more robustly towards adverse U.S. market news.

Lim (2007), Khalil (2014), Yi (2015) and Lingaraja et al. (2015) are instances of the second group of studies. Lim (2007) examined the dynamic linkages between the US market return and returns of ASEAN-5 stock markets based on daily data for the period between 2nd April 1990 and 31st August 2007 using VAR model and cointegration technique. The results pointed out that the cross-market correlations and mean returns for ASEAN-5 were higher and the market returns were less unstable in the post crisis period. The Granger causality test result designated an interdependence and integrated among ASEAN-5 stock market returns. The results also showed that the returns on the US stock market had a noteworthy effect on returns of ASEAN-5 stock markets. Khalil (2014) investigated the vibrant linkages between Pakistan Stock market and selected Asian stock markets in terms of China, India, Indonesia, Malaysia and Srilanka based on monthly closing stock prices indices for the period between November, 2003 and November, 2013 using correlation analysis, cointegration technique, Granger causality test and variance decomposition test. Granger causality test disclosed that Srilankan stock market is granger caused by India, Indonesia and Malaysia stock market. Whereas there subsist unidirectional causality from stock markets of India, Malaysia and Indonesia to stock market of Srilanka. But there was no long run association between Pakistan stock market and selected Asian stock markets. The variance decomposition showed that variances in Pakistan stock market and Indian stock market are because of their own market originality and other markets have no contribution to stock markets of Pakistan and India. Samadder et.al.(2015) investigated granger causality by some Asian and USA stock markets upon Indian stock markets from July.1990 to December,2012 in micro level taking window size of 250 data points along with correlation of probability of recurrence. They suggested that Asian stock markets may not have notable impact on Indian stock market compared to USA's impact and effect of granger causality increases in windows where both series are strongly connected.Yi (2015) investigated the extent of financial interdependence among financial markets of Asia in terms of China, Japan and Korea along with ASEAN financial markets for the period from 2001 to 2013 using cointegration, vector error correction model and variance decomposition analysis. The empirical results demonstrated that China, Japan, Korea, Hong Kong, Singapore and Taiwan had significant shocks on other stock markets and those impacts were spreaded to other markets for one or two months. Variances decomposition test result showed that Asian stock markets are noticeably persuaded by each other at every 6 month to the front, particularly by China and Korea had significant shocks of its own Korean innovations at every 6 month in front. Lingaraja et al. (2015) observed the survival of long-run portfolio diversification benefits and opportunities of eight emerging stock markets in Asia with three top developed stock markets based on share price indices for the period between January 01, 2005 and December 31, 2014.using factor analysis and graphical price movement diagram. The empirical results showed that each and every markets were closely linked, which is excellent for the global investors to diversify portfolios globally as it would propose improved stability of their economic profile and higher yields with less risk.

Valadkhani and Chancharat (2008), Thuan (2011), Shachmurove (2012) and Chiang and Chen (2016) study the upshot of different countries on a single country. Valadkhani and Chancharat (2008) examined the reality of cointegration and causality between the Thailand stock market and its most important trading partners in terms of the US, UK, Australia, Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan based on monthly data between December 1987 and December 2005 using financial econometrics. The empirical results of the Engle-Granger and the Gregory and Hansen (1996) test revealed that there was no proof of a long-run association between the stock prices of Thailand and those stock markets. Also, there were two unidirectional causalities running from the stock market returns of Thailand to Indonesia and the US stock markets. Furthermore, there was a bidirectional Granger causality between Thailand stock market and stock markets of Malaysia, Singapore and Taiwan. Thuan (2011) investigated the association of the US stock market with Vietnam stock market based on daily data for the period between 2003 and 2009 by using the Generalized Autoregressive Conditional Heteroscedasticity - Autogressive Moving Average and the Exponentially General Autoregressive Conditional Heteroscedasticity Autogressive Moving Average models. The empirical results showed that the U.S. market had a positive as well as significant persuade on the Vietnam stock market. Though, there was no proof of an instability upshot of the S&P 500 Index on the Vietnam-Index. The study confirmed that Vietnam was a feasible market economy however designated that fund managers' should think about stock market movement of the U.S. before making investment decisions in Vietnam. Shachmurove (2012) examined the linkages between the US stock market and the Middle East Stock markets in terms of Egypt, Israel, Jordan, Lebanon, Morocco, Oman and Turkey by using VAR models. The empirical results showed that the active linkages among these stock markets are comparatively small and suggested that benefits of portfolio diversification are available to the global investors. Chiang and Chen (2016) examined the dynamic conditional correlations of stock market returns between China and global stock markets. The results proposed that stock return correlations athwart markets are time-varying and exhibiting a structural change generated by an upward shift in China's implementation of economic liberalization and the incidence of the international financial crisis. The results also showed that the dynamic correlations were highest in case of Hong Kong, followed by Taiwan and Korea but the dynamic correlations with Europe and the US were low. Finally, the dynamic conditional correlations series were negatively related to the relative price-earning ratios and were positively related to the risk from the US stock market.

The literature review represents an extensive room for study regarding the associations between Indian stock market and selected other Asian stock markets. In India, this topic has not been tackled with appropriate importance. Therefore, the subject is still unanswered particularly in India.

3. Data and methodology

The present work is based on percentage change of daily closing value of time series data of Indian stock exchange and developed stock exchanges across Asia. If *X(t)* represents daily closing value of a stock market at the day t, then data under consideration for our work is $\left(\frac{X(t)-X(t-1)}{X(t)}\right)\times 100$. For this purpose, secondary data for seven Asian stock markets are analyzed; SENSEX (India-BSE), CSE All-Share (Srilanka-CSE), Dhaka Stock Exchange (Bangladesh-DSE), Hang Seng Index (Hong Kong-HSSE), KOSPI (South Korea-KOSPI), Nikkei 225(Japan-NIKKEI_225) and Shanghai Composite Index(China-SSE). Data source of these data is investing.com. Time interval for computation is taken from 2nd June, 2014 to 15th September, 2017. Number of data points in this interval is different for different indices; 813(BSE), 803(CSE), 656(DSE), 814(HSSE), 813(KOSPI), 833(NIKKEI_225) and 838(SSE). Eviews 7 package program has been used for arranging the data and conducting econometric analyses using Augmented Dickey-Fuller (ADF) unit root test, ADRL test and Granger (1969) causality test.

3.1 Augmented Dickey-Fuller Unit Root Test

Two or more time series with same order of integration variables are co-integrated if some linear combination of the variables is stationary. Cointegration is associated with systems of non-stationary variables, since any stationary variables are trivially cointegrated with other variables using a vector with coefficient 1 on the stationary component and coefficient 0 on the other components. So, the first step for analyzing cointegration is to check whether the time series variable is non-stationary or not. One of the ways to determine if the time series is non-stationary or not is to identify the presence of unit roots in each selected series. Presence of unit root in the tested series confirms that the time series is non-stationary. The Augmented Dickey-Fuller (ADF) unit root test has been used to check the stationarity of the time series data under consideration and to find the order of integration between them. The test has been performed by estimating VAR(p) model $y_t = \sum_{i=1}^{p} \theta_i y_{t-i} + e_t$

The ADF unit root test is based on the null hypothesis (H_0): unit root is present in y_t. This indicates that y_t is not *I(0)*,i.e.; y_t is not integrated of order 0 which implies y_t is non-stationary. Lower calculated ADF test statistics value than the critical value in a specified significance level suggest to reject null hypothesis implying stationarity of the data. If the data is found non-stationary at level, the ADF test is to be performed to the first difference of the data is used for testing a unit root. In this case, the data is said to be co-integrated of order one, *I(1)* or the data is first differenced stationary. If data is found non-stationary in first difference, The process is carried on to check order of integration of the data.

3.2 Johansen's Cointegration Test

In the next step, the Johansen's cointegration test has been applied to detect whether any long run association exists between the variables. This test is useful to check cointegration among several, say *k I(1)* time series. Let us consider a VAR (p) model $y_t = \mu + \sum_{i=1}^{p} \theta_i y_{t-i} + e_t$. The Johansen approach to cointegration test is based on two test statistics, namely, the trace test statistic, and the maximum eigenvalue test statistic. The trace test statistics can be specified as $\lambda_{trace}(r) = -\mathrm{T} \sum_{i=r+1}^{n} \ln(1-\lambda_i)$ where λ_i is ith largest eigen value of cointegration matrix Π and T is the number of observations. λ_i is estimated by calculating the characteristic root of Π in descending order. In the trace test, the null hypothesis (H_0) is that the number of distinct co-integrating vector(s) $r = r_1 < k$ against the alternate hypothesis (H_1) $r = k$. The maximum eigenvalue test statistics can be specified as $\lambda_{\max} = -\mathrm{T}\log(1-\lambda_{r+1})$ where $\lambda_{\max}$ is the (r+1)th largest squared eigen value. In the maximum eigenvalue test, the null hypothesis (H_0) $r = r_1 < k$ is tested against the alternate hypothesis (H_1) $r = r_1 + 1$. In both the process, if the test statistics is more than critical value at a specified significance level, we reject the null hypothesis.

3.3 Granger Causality Test

Granger causality test is useful to test whether lagged information on a variable *Y* is useful to forecast a variable *X* in the presence of lagged *X*. If not, then "*Y* does not Granger-cause *X* ", otherwise "*Y* Granger-cause *X*" (Granger, 1969). For a stationary time series, the test is performed using the level values of two variables and for non-stationary time series, order of the integration is used. There should be a causal association as a minimum in one way, if two series are found to be cointegrated in order one. In that circumstances to observe the causal association based on error correction model, Engel-Granger (1987) may be used. Suppose y_1 and y_2 are two cointegrating time series variables in that case equation for VECMs are

$$\Delta y_{1t} = \alpha_{10} + \gamma_1 z_{1,t-1} + \sum \alpha_{1,aj} \Delta y_{1,t-j} + \sum \alpha_{1,bj} \Delta y_{2,t-j} + \varepsilon_{1t}$$

$$\Delta y_{2t} = \alpha_{20} + \gamma_2 z_{2,t-1} + \sum \alpha_{2,aj} \Delta y_{1,t-j} + \sum \alpha_{2,bj} \Delta y_{2,t-j} + \varepsilon_{2t}$$

Where, $z_{1,t-1}$ and $z_{2,t-1}$ are error correction terms based on the cointegrating equation in VECM of Johansen's method. The direction of causality may be one way (unidirectional) or both way (bidirectional). For the short term causal effect, χ^2 -statistics on the lagged explanatory variables of the error correction model is used. For the long term causal effect, The t-statistics on the coefficients of the lagged error-correction term is calculated.

3.4 Variance decomposition Test

Granger causality only measures the exogeneity or endogeneity of the variables within sample period, but unable to deduce degree of exogeneity or endogeneity beyond sample period. For that purpose, variance decomposition method has been used which measures the percentage of a variable's forecast error variance that occurs as the result of a shock from a variable in the system. It is basically percentage of the fluctuation in y_{it} to other y_{jt} .If a variable is exogenous with respect to the other variables in the VAR (p) model, own shocks will explain all of the variable's forecast error variance (Sims, 1980).

Consider a VAR(p) model of m time series $y_{1t}, y_{2t} \ldots y_{mt}$ $\Phi(L) y_t = \varepsilon_t$ where $\Phi(L) = I_m - \Phi_1 L - \Phi_2 L^2 - \ldots + \Phi_p L^p$ is lag polynomial of order p with $m \times m$ coefficient matrices Φ_i , $i = 1, 2 \ldots p$.

If all $y_{1t}, y_{2t} \ldots y_{mt}$ are stationary, a Moving Average representation of y_t is obtained $y_t = \Phi^{-1}(L)\varepsilon_t = \Psi(L)\varepsilon_t$ where

$$\Psi(L) = I_m + \Psi_1 L + \Psi_2 L^2 + \ldots$$

Ψ_i 's can be obtained by the identity

$$\Phi(L)\Psi(L) = \left(I_m - \sum_{i=1}^{p} \Phi_i L^i \right)\left(I_m + \sum_{i=1}^{\infty} \Psi_i L^i \right) = I_m$$

Let $v_t = Q\varepsilon_t$

Then VAR(p) can be remodelled as

$$y_t = \Phi^{-1}(L)\varepsilon_t = \Psi(L)\varepsilon_t = \Psi(L)\mathrm{Q}^{-1} Q\varepsilon_t = \Psi(L)\mathrm{Q}^{-1} v_t = \Psi^*(L) v_t = \sum_{i=0}^{\infty} \Psi^*_i v_{t-i} .$$

s-step ahead forecast is then $\mathrm{E}_t(y_{t+s}) = \sum_{l=s}^{\infty} \Psi^*(l) v_{t+s-l}$.

The s step-ahead forecast error $e_{t+s} = y_{t+s} - \mathrm{E}_t(y_{t+s}) = \sum_{l=o}^{s-1} \Psi^*(l) v_{t+s-l}$.

Its *i*-th component is given by

$$e_{i,t+s} = \sum_{l=0}^{s-1}\sum_{j=1}^{m}\Psi_{ij}^{*}(l)v_{j,t+s-l} = \sum_{j=1}^{m}\sum_{l=0}^{s-1}\Psi_{ij}^{*}(l)v_{j,t+s-l}$$

. As the shocks are contemporaneously uncorrelated, error variance is given by

$$V(e_{i,t+s}) = \sum_{j=1}^{m}\sum_{l=0}^{s-1}V(\Psi_{ij}^{*}(l)v_{j,t+s-l}) = \sum_{j=1}^{m}\sum_{l=0}^{s-1}\left(\Psi_{ij}^{*}(l)\right)^{2}V(v_{j,t+s-l})$$

$$= \sum_{j=1}^{m}\left(\sum_{l=0}^{s-1}\left(\Psi_{ij}^{*}(l)\right)^{2}\right)$$

as shocks have unit variance. So, $\sum_{l=0}^{s-1}\left(\Psi_{ij}^{*}(l)\right)^{2}$ measures the error variance generated by shocks to y_j.

4. Empirical results and analysis

4.1 Correlation Statistics

Correlation analysis of stock markets is important as correlation measures a crude estimation of linear dependency between two stock markets. The pair-wise correlations of percentage change of daily closing price of stock indices in table 1 show that the pairwise correlation between almost all the stock markets are very low indicating possible gains from international diversifications.

Table – 1: Correlation Statistics

	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI_225	SSE
BSE	1						
CSE	-0.08	1					
DSE	-0.03	-0.03	1				
HSSE	0.22	-0.04	-0.02	1			
KOSPI	0.20	-0.08	0.04	0.22	1		
NIKKEI _225	0.04	-0.05	0.04	-0.03	-0.04	1	
SSE	-0.03	0.06	-0.04	0.04	-0.02	0.00	1

4.2 Unit Root Test Result

Augmented Dickey-Fuller (ADF) test is conducted to the levels of each individual series under consideration. It should be noted that as percentage change of daily closing value data is taken into account, data at level is equivalent to original closing price at first difference. Lag lengths were chosen according to the Schwartz Information Criterion (SIC) and Bartlett Kernel & Newey-West Bandwidth. The critical values are computed based on MacKinnon (1996); an asterisk indicates 5 percent level of significance.

The results of the Augmented Dickey-Fuller (ADF) test given in table 2 suggest that all the seven stock price indices in their change of percentage of daily closing value are stationary series at level. So, in first difference form, these daily closing value of stock price indices are stationary. Thus, all the chosen stock price variables are first-order integrated series, or *I(1)* processes.

Table 2: ADF Test Results at level (percentage change) or first difference(original data)

Stock Index	p-value*	t-stat value	c-value at 1%	c-value at 5%	Conclusion
BSE	0.00	-26.47	-3.97	-3.41	Stationary
CSE	0.00	-21.80	-3.97	-3.41	Stationary
DSE	0.00	-14.83	-3.97	-3.41	Stationary
HSSE	0.00	-27.70	-3.97	-3.41	Stationary
KOSPI	0.00	-28.05	-3.97	-3.41	Stationary
NIKKEI _225	0.00	-30.74	-3.97	-3.41	Stationary
SSE	0.00	-26.49	-3.97	-3.41	Stationary

*MacKinnon (1996) one- sided p-values.

4.3 Johansen Cointegration Test Result

As unit root test result emphasize the fact that all the time series variables under consideration are stationary or alternatively, all the closing value of stock markets are first difference stationary, there is a possibility of cointegration among them. Johansen's multivariate VAR(p) has been performed involving the seven stock prices chosen in the study where linear deterministic trends (restricted) are also allowed. The lag length of the VAR is calculated according to the minimum value of Schwartz Information Criterion (SIC), Akaike Information Criterion (AIC) and Hannan-Quinn Information Criterion (HQIC) and it is found to be 2. Cointegration test determines the rank (r) of the coefficient matrix based on Vector Auto Regression (VAR) model of the series, where the rank indicates existence of any cointegration, as well as the number of co-integrating vectors or relationships. For this purpose, two likelihood ratio tests are conducted, namely, the Trace Test (TT) and the Maximum Eigen Value test (MEV).

Table 3: Johansen Cointegration Test Results

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.38	1395.41	125.61	1.00
At most 1 *	0.31	1082.80	95.75	0.00
At most 2 *	0.30	839.80	69.81	0.00
At most 3*	0.24	609.78	47.85	0.00
At most 4*	0.23	425.47	29.79	0.00
At most 5*	0.19	252.66	15.49	0.00
At most 6*	0.16	112.47	3.84	0.00
Trace test indicates 7 cointegrating eqn(s) at the 0.05 level				
Unrestricted Cointegration Rank Test (Max-Eigen Value)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.38	312.61	46.23	0.00
At most 1 *	0.31	243.01	40.07	0.00
At most 2 *	0.30	230.00	33.87	0.00
At most 3*	0.24	184.31	27.58	0.00
At most 4*	0.23	172.82	21.13	0.00
At most 5*	0.19	140.19	14.26	0.00
At most 6*	0.16	112.47	3.84	0.00
Max-eigenvalue test indicates 7 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Table 3 describes the result of Johansen's cointegration test. The Trace test indicates the existence of seven co-integrating equations at 5% level of significance and the maximum eigenvalue test confirms this result. Thus, the selected variables of the study may have a long-run or equilibrium relationship.

4.4 Pairwise Granger Causality Test Results

As cointegration exists between the variables under study, they follow Vector Error Correction Model (VECM). Granger Causality-Wald test were performed based on VECM with purpose of detecting whether there is a causality relationship between variables in each model are shown in table 4. Optimum lag length is measured through Akaike Information Criterion, which are 2. The test is also performed in determining the direction of causation between these variables.

Note: *Significance at 5% level of significance, [ ] is probability value, ${\chi_{0.05}}^2(2) = 5.99$, # Lag 2 has been estimated using AIC criteria.

Table 4: Granger Causality Tests based on the Error Correction Model and Error Correction Model Test Results

Independent Stock Markets	Dependent Stock Markets						
	χ^2 Statistics						
	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
BSE	-	0.14 [0.93]	1.34 [0.51]	1.03 [0.60]	54.47 [0.00]*	1.06 [0.59]	5.79 [0.055]
CSE	0.15 [0.93]	-	5.20 [0.07]	4.22 [0.12]	3.05 [0.22]	1.39 [0.50]	0.16 [0.92]
DSE	1.54 [0.46]	0.61 [0.74]	-	4.32 [0.11]	5.61 [0.06]	0.05 [0.97]	4.18 [0.12]
HSSE	11.88 0.00]*	5.22 [0.07]	5.41 [0.07]	-	21.01 [0.00]*	3.39 [0.18]	43.20 [0.00]*
KOSPI	2.42 [0.30]	10.58 0.00]*	4.33 [0.11]	50.00 [0.00]*	-	2.02 [0.36]	28.45 [0.00*]
NIKKEI_225	0.19 [0.90]	4.88 [0.08]	3.49 [0.18]	3.53 [0.17]	5.16 [0.07]	-	12.94 [0.00]*
SSE	18.14 0.00]*	1.74 [0.42]	8.45 [0.01]*	28.66 [0.00]*	22.70 [0.00] *	1.87 [0.39]	-

During the period under study, Hong Kong stock market and Chinese stock market would significantly granger cause Indian stock market in the short-run. Again, only South Korean stock market and Srilankan stock market would notably granger cause in the short-run and only Chinese stock market would significantly granger cause in the short-run on Bangladeshi stock market. South Korean stock market and Chinese stock market has short term influence on Hong Kong stock market. But, on South Korean stock market, Indian stock market, Hong Kong stock market and Chinese stock market have short-term impact. It is interesting to observe that Japanese stock market is not granger caused by any other stock market under study in short run. Finally, on Chinese stock market, Hong Kong stock market, South Korean stock market and Japanese stock market has impact in the short-run. In brief, It is observed that there is a bidirectional causality running between HSSE $\leftrightarrow$ KOSPI & HSSE $\leftrightarrow$ SSE and KOSPI $\leftrightarrow$ SSE as well as unidirectional causality from

BSE $\rightarrow$ KOSPI, HSSE $\rightarrow$ BSE, KOSPI $\rightarrow$ CSE, NIKKEI_225 $\rightarrow$ SSE, SSE $\rightarrow$ BSE and SSE $\rightarrow$ DESE. It is also noticed that NIKKEI_225 is most exogenous stock market as it is not granger caused by any other stock market in this time period. KOSPI and SSE, being granger caused by most number of other variables have a chance to the most endogeneous variable. Also, granger causality test suggest that CSE and DSE may have no effect on any other stock markets as they do not granger cause any other market.

4.5 Variance Decomposition Analysis

Variance decomposition results based on vector error correction model with purpose of measuring the degree of exogeneity between different time series are shown in table 5 over a 10 times period. Cholesky Ordering obtained for this analysis is BSE, CSE, DSE, HSSE, KOSPI, NIKKEI_225 and SSE.

Table 5: Variance Decomposition Test Results

Variance Decomposition of BSE

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	0.98	100.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.06	97.51	0.00	0.00	0.85	1.13	0.06	0.44
3	1.14	95.75	0.004	0.10	1.98	1.59	0.079	0.50
4	1.28	96.59	0.010	0.10	1.56	1.27	0.07	0.41
5	1.37	96.35	0.01	0.08	1.68	1.33	0.08	0.46
6	1.45	96.20	0.01	0.08	1.80	1.41	0.08	0.41
7	1.54	96.41	0.01	0.08	1.68	1.36	0.09	0.37
8	1.61	96.40	0.01	0.07	1.70	1.37	0.09	0.35
9	1.69	96.42	0.01	0.07	1.71	1.38	0.08	0.32
10	1.76	96.50	0.01	0.06	1.67	1.37	0.09	0.30

Variance Decomposition of CSE

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	0.53	0.39	99.60	0.00	0.00	0.00	0.00	0.00
2	0.60	0.57	98.79	0.05	0.088	0.06	0.31	0.12
3	0.65	0.67	98.34	0.07	0.28	0.09	0.29	0.25
4	0.73	0.62	97.76	0.058	0.60	0.27	0.23	0.45
5	0.79	0.69	97.72	0.05	0.56	0.23	0.26	0.48
6	0.84	0.72	97.71	0.04	0.57	0.21	0.24	0.50
7	0.89	0.71	97.66	0.04	0.63	0.22	0.22	0.52
8	0.94	0.73	97.61	0.04	0.64	0.21	0.22	0.55
9	0.98	0.74	97.59	0.03	0.65	0.20	0.21	0.57
10	1.03	0.74	97.58	0.03	0.67	0.19	0.21	0.58

Variance Decomposition of DSE

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	0.80	0.01	0.01	99.98	0.00	0.00	0.00	0.00
2	0.86	0.03	0.48	99.03	0.17	0.13	0.02	0.14
3	0.95	0.04	0.81	98.00	0.15	0.69	0.16	0.14
4	1.07	0.03	0.68	97.84	0.36	0.67	0.18	0.23
5	1.14	0.03	0.74	97.78	0.33	0.68	0.22	0.20
6	1.22	0.03	0.82	97.73	0.30	0.74	0.21	0.18
7	1.30	0.03	0.80	97.74	0.32	0.75	0.18	0.17
8	1.36	0.02	0.81	97.73	0.31	0.78	0.18	0.16
9	1.43	0.02	0.83	97.73	0.30	0.80	0.17	0.15
10	1.49	0.02	0.83	97.73	0.30	0.81	0.16	0.14

Variance Decomposition of HSSE

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	1.21	5.34	0.18	0.18	94.29	0.00	0.00	0.00
2	1.30	8.72	0.23	0.84	86.38	1.55	0.22	2.05
3	1.38	10.55	0.24	0.84	81.48	4.28	0.22	2.39
4	1.51	10.59	0.32	0.75	79.16	4.76	0.32	4.09
5	1.61	11.91	0.29	0.73	77.57	4.90	0.30	4.29
6	1.69	12.56	0.27	0.67	76.28	5.53	0.28	4.40
7	1.78	12.89	0.26	0.64	75.37	5.78	0.28	4.77
8	1.86	13.48	0.24	0.61	74.29	6.07	0.27	5.04
9	1.94	13.83	0.22	0.57	73.57	6.35	0.26	5.18
10	2.01	14.10	0.21	0.55	73.03	6.51	0.26	5.34

Variance Decomposition of KOSPI

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	0.76	1.66	0.44	0.14	8.71	89.05	0.00	0.00
2	0.86	5.01	0.40	0.47	22.32	69.88	0.03	1.90
3	0.95	6.12	0.64	0.40	27.39	62.72	0.30	2.43
4	1.04	5.35	0.68	0.34	28.66	61.63	0.26	3.07
5	1.12	6.47	0.60	0.34	30.45	58.74	0.27	3.13
6	1.18	6.81	0.60	0.32	31.97	56.91	0.27	3.12
7	1.25	6.67	0.60	0.29	33.37	55.41	0.27	3.37
8	1.32	6.94	0.58	0.29	34.31	54.09	0.28	3.51
9	1.38	7.08	0.57	0.28	35.08	53.17	0.28	3.54
10	1.43	7.11	0.56	0.26	35.81	52.34	0.28	3.61

Variance Decomposition of NIKKEI_225

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	1.60	0.06	0.00	0.06	0.19	0.52	99.18	0.00
2	1.67	0.09	0.18	0.05	0.18	0.69	98.74	0.06
3	1.84	0.12	0.21	0.05	0.17	0.79	98.31	0.34
4	2.05	0.12	0.17	0.04	0.14	0.95	98.27	0.30
5	2.17	0.12	0.21	0.04	0.13	0.94	98.25	0.30
6	2.32	0.11	0.21	0.04	0.12	0.97	98.20	0.34
7	2.45	0.10	0.20	0.04	0.11	1.03	98.19	0.34
8	2.57	0.09	0.21	0.04	0.10	1.04	98.18	0.34
9	2.70	0.09	0.21	0.04	0.09	1.06	98.16	0.35
10	2.81	0.08	0.20	0.03	0.08	1.07	98.16	0.36

Variance Decomposition of SSE

Period	S.E.	BSE	CSE	DSE	HSSE	KOSPI	NIKKEI _225	SSE
1	1.93	0.68	0.46	0.00	0.72	2.17	0.11	95.85
2	2.10	1.02	0.39	0.67	1.96	5.61	0.13	90.22
3	2.24	1.98	0.35	0.66	2.94	8.38	0.88	84.81
4	2.48	1.93	0.38	0.54	5.10	9.94	0.76	81.35
5	2.65	1.96	0.33	0.57	4.96	10.41	0.67	81.09
6	2.79	2.23	0.30	0.59	5.14	11.15	0.76	79.82
7	2.95	2.28	0.30	0.54	5.76	11.88	0.72	78.50
8	3.09	2.32	0.28	0.53	5.92	12.36	0.70	77.88
9	3.22	2.42	0.26	0.53	6.04	12.75	0.70	77.28
10	3.36	2.47	0.26	0.51	6.26	13.11	0.69	76.69

Variance decomposition analysis shows that NIKKEI_225 is most exogenous variable as highest proportion of shocks (98.16%) can be explained by its own innovation compared to other stock markets. This result is consistent with granger causality analysis. Also it is evident that shock to CSE and DSE does not have any significant effect on any other stock markets. We fix that a innovation of stock market explains another stock market if the forecast error variance is more than 5%.. Innovation of HSSE explain forecast error variance of BSE (14.10%), KOSPI (6.51%) & SSE (5.34%); innovation of KOSPI explain forecast error variance of BSE (7.11%) & HSSE (35.81%); innovation of SSE explain forecast error variance of HSSE (6.26%) and KOSPI (13.11%). All these results are match with granger causality analysis. It is also indicated that KOSPI is most endogenous variable as it explains only 52.34% of the forecast error variance by its own innovation which is least among the variables under the study.

5. Conclusions

The objective of this paper is to study the linkages among Asian stock markets. We conclude that pairwise correlation of the selected Asian stock markets are very low indicating potential gains from international diversifications for investors. Our time series stock index values are stationary at first differenced. Johansen cointegration test results indicate that Asian stock markets are associated in the long-run in the same order. Granger pairwise test based on error correction model test results show that there exist a bidirectional causality running between (i) Hong Kong stock market and South Korea stock market, (ii) Hong Kong stock market and Chinese stock market and (iii) South Korean stock market and Chinese stock market as well as unidirectional causality from (i) Indian stock market to South Korean stock market, (ii) Hong Kong stock market to Indian stock market, (iii) South Korean stock market to Srilankan stock market, (iv) Japan stock market to Chinese stock market, (v) Chinese stcok market to Indian stock market and (vi) Chinese stock market to Bangladesh stock market. Both Granger causality and variance decomposition analysis shows that Japan stock market is most exogenous variable because Japan stock market is not granger caused by any other stock market as well as highest proportion of shocks can be explained by its own innovation compared to other stock markets. It is also evident that shock to Srilanka and Bangladesh stock markets do not have any significant effect on any other stock markets. These findings confirm that there are important opportunities for global investors to diversify their portfolios in these stock markets.

References

Bhunia, A. and Yaman, D. (2017). Is There a Causal Relationship Between Financial Markets in Asia and the US?. *The Lahore Journal of Economics*, *22* (1), 71–90.

Engle, R. F. and Granger, C. W. J. (1987). Cointegration and error correction: Representation, estimation and testing. *Econometrica, 55*, 251-276.

Francis, B. B. and Leachman, L. L. (1998). Superexogeneity and the dynamic linkages among international equity markets. *Journal of International Money and Finance*, *17*, 475-492. Retrieved from https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/1964/francis_superexogeneity_and_the_dynamic.pdf?sequence=1

Gjerde, Øystein & Sættem, Frode. (1995). Linkages among European and world stock markets. *The European Journal of Finance*, *1*, 165-179. Retrieved from https://www.researchgate.net/publication/226641453_Linkages_among_European_and_world_stock_markets

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, *37* (3), 424–438.

Hung, B. and Cheung, Y. (1995). Interdependence of Asian emerging equity markets. *Journal of Business Finance and Accounting*, *22*, 281-288.

Khalil, Jebran (2014). Dynamic Linkages between Asian Countries Stock Markets: Evidence from Karachi Stock Exchange. *Research Journal of Management Sciences*, *3*(5), 6-13. Retrieved from http://www.isca.in/IJMS/Archive/v3/i5/2.ISCA-RJMS-2014-44.pdf

Lim L.K. (2007). Linkages Between ASEAN Stock Markets: A Cointegration Approach. 1818-1824. Retrieved from https://www.mssanz.org.au/MODSIM07/papers/29_s1/Linkages Between_s1_Lim_.pdf

Lingaraja, K., Selvam, M., Vasanth, V. and Ramachandran, R. R. (2015). Long-run Overseas Portfolio Diversification Benefits and Opportunities of Asian Emerging Stock Markets and Developed Markets. *International Journal of Economics and Financial Issues*, *5*(2), 324-333. Retrieved from file:///C:/Users/win%207/Downloads/1162-3517-1-PB%20(1).pdf

Luu Tien Thuan (2011). The Relationship between the United States and Vietnam Stock Markets. *The International Journal of Business and Finance Research*, *5*(1), 77-89. Retrieved from ftp://ftp.repec.org/opt/ReDIF/RePEc/ibf/ijbfre/ijbfr-v5n1-2011/IJBFR-V5N1-2011-6.pdf

Masih, R. and Masih, A. M. M. (2001). Long and short term dynamic causal transmission amongst international stock markets. *Journal of International Money and Finance*, *20*, 563-587.

Park, C. (2013). Asian Capital Market Integration: Theory and Evidence. *ADB Economics Working Paper Series*, 1-27. Retrieved from *https://www.adb.org/sites/default/files/publication/30284/ewp-351.pdf*

Samadder, S., Ghosh, K. and Basu, T.(2015). Causality Analysis of US Stock Market over Indian Stock Market. *Journal of International Academy of Physical Sciences*, *19*(3), 213-232.

Shachmurove, Yochanan (2012). Dynamic Co-movements of Stock Indices: The Emerging Middle Eastern and the United States Markets. Retrived from economics .sas.upenn.edu/system/files/01-18.pdf

Sims C. (1980). Macroeconomics and Reality. *Econometrica*, *48*(1), 1-49.

Stan Shun-Pinn Lee and Kim-Leng Goh (2016). Regional and International Linkages of the ASEAN-5 Stock Markets: A Multivariate Garch Approach. *Asian Academy of Managemen Journal of Accounting and Finance*, *12*(1), 49–71. Retrieved from http://web.usm.my/journal/aamjaf/vol%2012-1-2016/aamjaf120116_03.pdf

Thomas C. Chiang and Xiaoyu Chen (2016). Empirical Analysis of Dynamic Linkages between China and International Stock Markets. *Journal of Mathematical Finance*, *6*, 189-212. Retrieved from http://www.scirp.org/journal/jmf http://dx.doi.org/10.4236/jmf.2016.61018

Tiwari, A. K., Dar, A. B., Bhanja, N. and Shah, A. (2013). Stock Market Integration in Asian Countries: evidence from Wavelet multiple correlations. *Journal of Economic Integration*, *28*(3), 441-456. Retrieved from http://www.e-jei.org/upload/JEI_28_3_441_456_2013600021.pdf

Yi, C. D. (2015). Linkages among Asian Stock Markets using a Vector Error Correction Model. *Journal of Economic Theory and Econometrics*, *26*(4), 1–25. http://es.re.kr/eng/upload/jetem-26-4-1.pdf

Valadkhani, A. and Chancharat, S. (2008). Dynamic Linkages between Thai and International Stock Markets, *Journal of Economic Studies*, *35* (5), 425-441. Retrived from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.472.7137&rep=rep1&type=pdf