A STUDY OF GRANGER CAUSALITY IN ASIAN STOCK MARKETS
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Introduction
There has been a phenomenal rise in the Asian economies since the late 1990’s, especially in China and India, particularly with the introduction of economic reforms and liberalization in both of these economies. Especially since the 2001 slowdown of the US economy, which affected almost all global economies, the Asian “giants” have emerged as potential economic superpowers, with growth rates touching almost 10% per annum, and expected to increase even more. Japan, which had achieved very high levels of growth in the 1960’s and the early 1970’s, faced economic stagnation from the 1990’s, and was adversely hit by the 2001 global slowdown. The South-East Asian “tigers,” which had emerged on the global economic scene in the 1980’s, were also affected hit by the Asian financial crisis in the late 1990’s, and were further constrained by the 2001 global slowdown. The post-2001 growth of Japan and the South-East Asian “tigers” was encouraging, but far behind that of the “giants.”

The study of the inter-linkages between Asian stock markets is necessitated by their rapid growth and development in recent years. It is of in particular importance to study whether the long-run movement of the stock returns of the different markets has any common driving forces, or whether they are driven solely by their own fundamentals. It is also necessary to identify the lead-lag relationship between various international markets, i.e. to identify markets, which play a more dominant role in influencing other markets’ stock returns. Such inter-linkages would have profound consequences for the effectiveness of macroeconomic policies of the countries concerned.

Literature Review
There is a vast literature examining the integration of global equity markets, though most of the studies pertain to the developed markets. The literature concerned with emerging markets started only in the late 1990’s, mainly due to the South-East Asian crises. Though studies have shown that the US market, and more so the Japanese market, played major roles in the integration of Asian markets (Fatnassi and Abaoub, 2012), there were mixed results regarding cointegration of Asian markets with both the US and Japanese ones. On the other hand, the influence of the US market was stronger than that of Japan in terms of information leadership in the Asian region (Kim, 2005).

There are also mixed results regarding the role of the South-East Asian financial crises in the integration of Asian markets. Some studies found significant long-run relationships between Asian markets before and during/after the crisis, and some studies also showed that both the Japanese and US influences were insignificant during the pre-crisis period, as well as significant during/after the crisis period (Choudhry and Lin, 2004). The results pertaining to financial markets in the Asia Pacific region, thus indicate that they are neither well integrated nor completely segmented.

Yang and Lim (2002) studied integration among nine Asian stock markets, and found some evidence of short-term linkages among these markets, and a significant difference pre- and post-Asian crisis. Further, they found no evidence of long-term
equilibrium trending relationship among South-East Asian stock markets. They also found that the Japanese market was isolated from the South-East Asian markets.

Hashmi (2002) studied inter-linkages between South-East Asian financial markets, and found that they have increased after the emergence of the South-East Asian crisis. The US market was found to affect the South-East Asian markets but was not affected by them, while the Japanese market was relatively isolated from them. The Singapore market was the dominant market in the region, exhibiting greater effect than the US market. All the South-East Asian markets considered were found to affect one another and their effects were found to be transmitted mostly within two days.

Henry et al. (2006) also studied inter-linkages between South-East Asian financial markets, taking into consideration possible asymmetry in time-varying conditional volatility. They found return and volatility linkages across the markets, with stronger inter-linkages between volatilities than between returns. However, they found that the Japanese market did not Granger-cause either mean or conditional volatility of other South-East Asian markets, while they found that the Hong Kong and Singapore markets linearly and nonlinearly Granger-cause Japanese market returns; and they found that the South Korean market was isolated from other South-East Asian markets.

Nath and Patel (2003) studied the inter-linkages between the Indian market and some leading emerging markets and developed markets using Granger causality, Johansen’s cointegration, and the VAR framework to test the same. They found no long-term equilibrium relationship among the markets, but significant short-term relationships among the emerging markets apart from India, and some Granger causality from the global markets to Indian market.

Bose (2005) studied the integration of the Indian market with some major Asian markets and the US market. Overall, he found that after the South-East Asian crisis the Indian market was not isolated from the Asian and US markets. He found that the Indian market was linked with the US market through other Asian markets, which were closely linked with both of them. He also found that Indian markets exerted some influence on major markets like Japan, Korea, Taiwan, and Malaysia. He further found that the Indian market belonged to a group of Asian markets, which were moderately cointegrated within themselves and with the US market.

Several studies have suggested that international stock markets have become increasingly integrated in recent times, due to such factors as international financial market deregulation, adoption of floating exchange rates, advancements in communication and information technology, lower cost of transactions, and new financial innovations. For an emerging economy like India, with a significant transformation in its stock market post-liberalization, it is important to understand the pattern of inter-linkages with other Asian markets, as this would have profound implications on international portfolio construction and vulnerability/risk management.

The present study investigates Granger causality between the Indian stock market and the Chinese, Japanese, and South-East Asian stock markets.

Materials and Methods

The present study investigates Granger causality (Dash, 2014) between stock markets in some emerging Asian economies. The stock market indices chosen for the study were that of India’s BSE SENSEX 30 (Bombay Stock Exchange Sensitive
Index), China’s SSE (Shanghai Stock Exchange), South Korea’s KOSPI 200 (Korea Composite Stock Price Index), and Japan’s NIKKEI 225 (Nihon Keizai Shimbun, Tokyo Stock Exchange).

Though this sample is quite small, it does reflect certain broad trends in Asian stock market behaviour. Stock markets such as that of Russia and those of Middle Eastern markets were not considered, because they are very tightly regulated and do not reliably reflect underlying investors’ sentiments. Of the South-East Asian markets, only South Korea’s KOSPI was considered; other South-East Asian stock exchanges would be expected to behave similarly. The sample, thus, represents the major, relatively reliable Asian stock market indices. The data for the present study consisted of the daily closing prices of the sample stock market indices over the period from January 1, 2000 to July 31, 2007. The data was collected from the Yahoo Finance website.

The objective of the study was to investigate causality between the sample stock markets. For this, all of the concerned time series must be stationary. The augmented Dickey-Fuller unit root test was used to establish the stationarity of the series. The model for this test is given by:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{m} \delta_i \Delta y_{t-i} + \epsilon_t,$$  \hspace{1cm} (1)

where $\Delta y_t = y_t - y_{t-1}$ is the first order forward difference in the time series $\{y_t\}$, $y_{t-1}$ the one-period lag in the time series $\{y_t\}$, and $\Delta y_{t-i}$ are lagged values of $\Delta y_t$. The coefficient $\alpha$ represents the drift parameter, $\beta$ represents the trend parameter, and $\gamma$ represents the unit root. Finally, the order $m$ is the optimal lag chosen by Akaike’s (1969) information criterion. The null hypothesis of the presence of a unit root is rejected if the estimated value of $\gamma$ is statistically significant and negative.

The following modified linear Granger causality tests were employed (Granger, 1969). To assess the effect of the explanatory stock market index $j_0$ on the dependent stock market index, the Granger causality tests involve the estimation of the following models:

(a) the unrestricted model:

$$\Delta y_t^{j_0} = a + \sum_{i=1}^{p_0} b_i^{j_0} \Delta y_{t-i}^{j_0} + \sum_{j=1}^{k} \sum_{i=0}^{p_j} b_j^{i} \Delta y_{t-i}^{j} + \epsilon_{t},$$  \hspace{1cm} (2)

where $\Delta y_t^{j_0}$ is the first order forward difference in the daily closing prices of the dependent stock market index, and $\Delta y_t^{j}$ is the first order forward difference in the daily closing prices of the explanatory stock market indices.

(b) the restricted model (excluding the stock market index $j_0$):

$$\Delta y_t^{j_0} = a + \sum_{i=1}^{p_0} b_i^{j_0} \Delta y_{t-i}^{j_0} + \sum_{j \neq j_0}^{p_j} \sum_{i=1}^{p_j} b_j^{i} \Delta y_{t-i}^{j} + \epsilon_{t}.$$  \hspace{1cm} (3)

The coefficients $a$, $b_i^{j_0}$, and $b_j^{i}$ are the parameters to be estimated in the regressions, and the orders $p_0$ and $p_j$ are the optimal lags chosen by Akaike’s (1969) information criterion. In order to test the significance of the effect of the explanatory stock market index $j_0$ on the dependent stock market index, the usual F-statistic as
below is employed:

\[
F = \frac{(\text{SSE}_k - \text{SSE}_{\text{UR}})}{(\text{df}_k - \text{df}_{\text{UR}})} / \text{MSE}_{\text{UR}}.
\] (4)

The null hypothesis of no Granger causality of the explanatory stock market index \( j_0 \) on the dependent stock market index would imply that the coefficient \( b_j^0 \) is nil. Thus, if the coefficient \( b_j^0 \) is statistically significant, it can be inferred that changes in the explanatory stock market index \( j_0 \) cause changes in the dependent stock market index.

\section*{Results}

\subsection*{Unit Root Tests}

The augmented Dickey-Fuller unit root tests were performed for the selected stock market indices to determine stationarity. The results of the tests are shown in Table 1.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|l|}
\hline
Independent variables & Unstandardised coefficients & Standardised coefficients & p-value (one-tailed) \\
\hline
& (constant) & -2.0526 & 0.37730 \\
Trend & 0.0279 & 0.1197 & 0.00150 \\
first order lag in SENSEX & -0.0030 & -0.0683 & 0.04535 \\
& (constant) & 18.4926 & 0.23735 \\
Trend & 0.0312 & 0.0698 & 0.00615 \\
first order lag in NIKKEI & -0.0037 & -0.0531 & 0.02240 \\
& (constant) & 2.7177 & 0.05800 \\
Trend & 0.0046 & 0.1166 & 0.00125 \\
first order lag in KOSPI & -0.0072 & -0.0990 & 0.00540 \\
& (constant) & 15.312 & 0.01355 \\
trend & -0.0041 & -0.0804 & 0.04425 \\
first order lag in SSE & -0.0078 & -0.1098 & 0.01095 \\
\hline
\end{tabular}
\caption{Results of Augmented Dickey-Fuller Unit Root Tests}
\end{table}

The results of the ADF unit root tests indicate that, for all the selected stock market indices, the null hypothesis of a unit root is rejected. The tests also indicate that, for all the selected stock market indices, there is a significant trend component, and, in particular, for the SSE, there is also a significant drift component. As a consequence of the rejection of any such unit root processes in the selected stock market indices, it can be concluded that the returns series under study are stationary.

\subsection*{Granger Causality Tests}

The Granger causality tests were performed to test the direction of causality between the selected stock market indices. In performing the tests, a lag structure of twenty lags was chosen, as autocorrelations in the first order differences in all of the selected stock market indices were significant up to twenty lags. The results of the tests are shown in Table 2.

The results of the Granger causality regressions indicate that there was significant causality of KOSPI on NIKKEI (with variation in changes in KOSPI explaining 2.16% of the variation in changes in NIKKEI), of NIKKEI on SENSEX
(with variation in changes in NIKKEI explaining 54.66% of the variation in changes in SENSEX), of SENSEX on KOSPI (with variation in changes in SENSEX explaining 2.72% of the variation in changes in KOSPI), and of SENSEX on SSE (with variation in changes in SENSEX explaining 3.08% of the variation in changes in SSE). Other effects were found to be non-significant. Thus, there is evidence of unidirectional Granger causality from KOSPI to NIKKEI, from NIKKEI to SENSEX, and from SENSEX to KOSPI and to SSE.

### Table 2. Results of Granger Causality Tests

<table>
<thead>
<tr>
<th>INDEX</th>
<th>CAUSALITY</th>
<th>$\Delta(R^2)$</th>
<th>$\Delta(adj. R^2)$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIKKEI</td>
<td>KOSPI→NIKKEI</td>
<td>0.0216</td>
<td>0.0077</td>
<td>0.0614</td>
</tr>
<tr>
<td></td>
<td>SSE→NIKKEI</td>
<td>0.0193</td>
<td>0.0053</td>
<td>0.1297</td>
</tr>
<tr>
<td></td>
<td>SENSEX→NIKKEI</td>
<td>0.0187</td>
<td>0.0046</td>
<td>0.1557</td>
</tr>
<tr>
<td>SENSEX</td>
<td>KOSPI→SENSEX</td>
<td>0.0134</td>
<td>-0.0002</td>
<td>0.4791</td>
</tr>
<tr>
<td></td>
<td>SSE→SENSEX</td>
<td>0.0160</td>
<td>0.0025</td>
<td>0.2662</td>
</tr>
<tr>
<td></td>
<td>NIKKEI→SENSEX</td>
<td>0.5466</td>
<td>0.0429</td>
<td>0.0000</td>
</tr>
<tr>
<td>KOSPI</td>
<td>SENSEX→KOSPI</td>
<td>0.0272</td>
<td>0.0137</td>
<td>0.0069</td>
</tr>
<tr>
<td></td>
<td>NIKKEI→KOSPI</td>
<td>0.0191</td>
<td>0.0053</td>
<td>0.1284</td>
</tr>
<tr>
<td></td>
<td>SSE→KOSPI</td>
<td>0.0172</td>
<td>0.0033</td>
<td>0.2207</td>
</tr>
<tr>
<td>SSE</td>
<td>SENSEX→SSE</td>
<td>0.0308</td>
<td>0.0172</td>
<td>0.0018</td>
</tr>
<tr>
<td></td>
<td>KOSPI→SSE</td>
<td>0.0109</td>
<td>-0.0036</td>
<td>0.7688</td>
</tr>
<tr>
<td></td>
<td>NIKKEI→SSE</td>
<td>0.0200</td>
<td>0.0059</td>
<td>0.1085</td>
</tr>
</tbody>
</table>

### Conclusions

The present study has analyzed Granger causality between the Indian stock market and the Chinese, Japanese, and South-East Asian stock markets. The results of the study indicate that there is evidence of unidirectional Granger causality from KOSPI to NIKKEI, from NIKKEI to SENSEX, and from SENSEX to KOSPI and to SSE. This suggests that the Indian stock market is closely integrated with the South-East Asian markets and the Japanese market. In fact, even though SENSEX is part of a causality chain with KOSPI and NIKKEI, there is no evidence of bidirectional causality between SENSEX and KOSPI and NIKKEI. Further, the Chinese market is influenced by the Indian market, but in turn does not seem to exert influence on any of the markets. The results, thus, indicate integration of the Indian and Japanese markets with the South-East Asian markets, and relative isolation of the Chinese market.

The results concur with the literature, which generally suggests, that the Indian market is integrated with South-East Asian markets, but are at variance with the results of several studies, which suggest that the Japanese market is isolated from the South-East Asian markets. In terms of information leadership between markets, the results concur with Bose’s (2005) findings of SENSEX’s information leadership on the KOSPI and NIKKEI’s information leadership on the SENSEX, but do not concur with her findings of KOSPI’s information leadership on the SENSEX.

The study has some limitations. Only four stock markets have been considered in the study, and this may have distorted the results; also, the South-East Asian markets are relatively under-represented. Also, the study period avoids the global financial meltdown and its aftermath, as it would affect the stationarity of the data; in fact, the interlinkages after the global financial meltdown would be expected to be quite different from the results obtained. These would need to be investigated in further studies. Also, the study has analysed linear Granger causality only, and also has not
investigated cointegration. There is a wide scope for further research to explore the interlinkages between the Indian market and global markets taking these aspects into consideration.

References

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Abstract
This study investigates the inter-linkages between the Indian stock market and the Chinese, Japanese, and South-East Asian stock markets, during 2000-2007, prior to the global financial crisis, using the augmented Dickey-Fuller test to test the returns series for stationarity, and the Granger causality test to test for causality of returns between the markets. The results of the study suggest that the Indian stock market is closely integrated with the South-East Asian markets and the Japanese market, and that the Chinese market is influenced by the Indian market, but in turn does not seem to exert influence on any of the markets. The results, thus, indicate integration of the Indian and Japanese markets with the South-East Asian markets, and relative isolation of the Chinese market.

Keywords: inter-linkages between stock markets, augmented Dickey-Fuller test, Granger causality test