AN EXPLORATION ON VOLATILITY ACROSS INDIA AND SOME DEVELOPED AND EMERGING EQUITY MARKETS

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The opening up of financial markets in India has led to significant transformation within the financial sector, which has become more integrated with international stock markets. The general concern which is emerging with such development is the increased volatility of equity returns. This paper explores the relationship between volatility within not only the Indian equity market but also within other developed and emerging markets as well. Based on a daily data set for more than nine years, this paper estimates a joint Vector Auto Regression/Multivariate Generalized Autoregressive Conditional Heteroskedasticity (VAR-MGARCH) model. As the existing literature suggests, returns in the United States of America, the Republic of Korea and Hong Kong, China have a definite effect on returns in India. More interesting is the finding that Indian market returns also affect the returns in other markets such as Japan, the Republic of Korea, Singapore and Hong Kong, China. In addition, return volatility of the Indian market does not have an increasing or declining trend, but exhibits sudden sharp increases over the sample period. The conditional correlation of the Indian equity market return with all the other markets has increased over time in recent years.

JEL Classification: F36, G15.

Key words: Volatility transmission, Indian equity market, market integration, volatility linkage.

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I. INTRODUCTION

In India, liberalization measures in the financial sector have been in vogue since the 1990s. This has led to considerable development of the capital market. The movement of some variables related to the stock market clearly points to this development. For example, during the financial years between 1992/93 and 2008/09, the number of trading days in the Bombay Stock Exchange (BSE) increased from 192 to 243, turnover from Rs. 456,960,000,000 to Rs. 11,000,740,000,000 and market capitalization on BSE from Rs. 188,146 to Rs. 30,860,750,000, implying a sixteen-fold increase. The stock market index (BSE Sensex) has also shown a phenomenal rise, especially in the past few years. For example, from June 2004 to January 2008, the Sensex jumped from 4,835 to 20,873, indicating a growth of more than 300 per cent. The improvement can also be observed in terms of stock returns. The average daily return on BSE was 0.23 in 2003, compared to 0.08 in the United States of America, 0.09 in the United Kingdom of Great Britain and Northern Ireland and 0.12 in Japan, Singapore and Hong Kong, China. During 2007, the return in BSE was 0.2 which is quite comparable to stock markets in developed countries.[1] Interestingly, the return in most of the Asian markets has been impressive, providing an immense opportunity for domestic and foreign investors to increase their potential gains.

In this process of gradual liberalization, the Indian equity market has also become more integrated with other developed and emerging markets in Asia. For example, Bekaert and others (1998) shows that free international capital mobility and growing financial integration are directly related to the movements of stock prices of various national markets. Using data on 20 emerging markets, including India, it is shown that stock market returns within these countries are mirroring the world market return. This is a result of the introduction of liberalization measures in the relevant financial sectors. Brooks and Catao (2000), in a March 1986 through August 2000 study involving 21 developed and 19 emerging countries, including India, found evidence of stock market integration operating through the channel of information technology (IT) industry.[2] Literature on the co-movement of stock returns, concerning the emerging markets in the Asia-Pacific region, has mixed evidences. Most of the work suggests that post-Asian crisis, some markets have cointegrated with the United States and some have cointegrated with Japan, while a few others have not cointegrated with either (Ghosh and others, 1999; Yang and Lim, 2002; Choudhry and Lin, 2004). In general, the studies conclude that markets can be said to have only

[1] The Securities and Exchange Board of India (SEBI) Handbook of Statistics on the Indian Securities Market 2009.

[2] See also Mukherjee and Bose (2008).

partially converged. As a result, researchers are claiming that financial markets in the Asia-Pacific region are neither well integrated nor completely segmented.

However, with increased financial integration, there is an emerging concern among financial analysts and academia that Indian equity market volatility has increased substantially. As a result of this increased integration with stock markets internationally, the return volatility in other markets might be having a significant impact on the volatility in the Indian market. This concern is justified because the evidence demonstrates that the Indian market moves together with markets like Japan, the Republic of Korea, Singapore, the United States and Hong Kong, China (Mukherjee and Bose, 2008).[3] There are very few papers that directly deal with this issue in the Indian context. This paper makes an attempt to find out whether volatility in other developed/developing markets affected the volatility of the Indian market in the recent past.

Volatility spillover affects policy on two fronts: (a) the portfolio manager and (b) the government or regulatory authority. An international portfolio manager invests in a number of emerging and developed markets as this leads to portfolio diversification. Emerging economy markets, when compared to those in developed economies, generally offer a higher rate of return as well as more risk to investors. When choosing the optimal portfolio, the manager must be aware of the potential volatility of the returns as well. If he has information on the volatility linkage among countries, he will be in a better position to make informed of decisions regarding his portfolio. With volatility linkage, comes the possibility of policy implications related to contagion. With liberalization, foreign investors increasingly invest in emerging markets. A sudden withdrawal on part of such investors may destabilize the home country's market even if the fundamentals are strong. This may hinder economic growth as well. Therefore, an analysis of volatility within financial markets of emerging countries will provide useful insights to policy makers, allowing for further opening up of the markets in line with the global liberalization process. For example, if it is observed that country A's volatility of returns is influenced by that of country B, then the authority should closely observe events of that country B in order to prevent possible collapse in country A. The authority may consider imposing restrictions on foreign investments if necessary in periods of economic turbulence.

There exists substantial literature on volatility spillover in developed markets, such as studies dealing with theoretical aspect as well as empirical estimation of such volatility spillover. For example, King and Wadhwani (1990) found evidence of contagion for the New York, London and Tokyo stock markets. Hamao and others

[3] See also Wong and others (2005).

(1990) observed volatility spillovers from the stock markets of the United States and the United Kingdom to the Japanese stock market (Badrinath and Apte, 2005). Most of these works used variations of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models like exponential GARCH, univariate as well as multivariate GARCH. For instance, Bala and Premaratne (2004) examined volatility spillover concerning developed markets using the Multivariate GARCH model with Glosten-Jagannathan-Runkle (GJR) extensions as well as other methods (see also Ledoit and others, 2003). Forbes and Rigobon (1999) tested for stock market contagion, following a different approach, during the 1997 East Asian crises, the 1994 Mexican peso collapse, and the 1987 United States stock market crash, with 28 emerging markets from East Asia and Latin America, including India. It prescribed a new measure for contagion and found that no contagion implying that high market co-movements during these periods was a continuation of strong cross-market linkages.

There exist a few studies that examine the volatility spillover concerning the Indian equity market as well. For example, Kumar and Mukhopadhyay (2007) investigated short term linkages between National Association of Securities Dealers Automated Quotations (NASDAQ) of the United States and National Stock Exchange (NSE) of India for 1999-2001 and found that the effect of NASDAQ daytime return volatility shocks on NSE 50 Nifty Index (Nifty) overnight return volatility is 9.5 per cent and that of Nifty daytime return is a mere 0.5 per cent on average. In addition, Mukherjee and Mishra (2005) examined the return and volatility spillover to the Indian stock market from 12 other developed and emerging Asian countries[4] for the period of November 1995 to May 2005. They found that contemporaneous intraday return spillover among India and almost all the Asian countries are found to be positive and significant. Moreover, the foreign market return spillover significantly affected the Indian open-to-close return much more than that of its close-to-open return. Mainly, the volatility spillovers to BSE were from the Republic of Korea and Hong Kong, China.

The objective of this paper is to augment the findings already obtained on Indian equity return volatility with more recent data, ranging more than nine years and covering many Asian and developed countries. The previous studies either deal with NSE or BSE as representative of the Indian market with data dating back to 2005. In that time the Indian stock market has come a long way, and therefore the relation should be examined regarding the recent past. This paper attempts to examine this matter with the most recent data of the BSE Sensex. It deviates from contemporary

[4] India, China, Hong Kong, China, Indonesia, Japan, the Republic of Korea, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan Province of China and Thailand.

studies on volatility transmission concerning the Indian economy in its coverage of countries, choice of sample period and method of analysis. Those markets, whose co-movements with the Indian market in terms of equity returns are already found in the literature, are included in this study. The analysis is based on daily data for more than nine years in the recent past. In addition, to explore the relation between the equity return volatility of India and other international markets, a multivariate GARCH model is estimated. Instead of the frequently applied Auto Regressive Moving Average-GARCH (ARMA-GARCH) model, an appropriate VAR-MGARCH model is estimated jointly to capture the interaction of the market returns in terms of their mean, variance and covariance.

The structure of the paper is as follows: section II provides an overview of volatility in the Indian stock market; section III discusses data and methodology; section IV presents the results and section V concludes the paper.

II. STOCK MARKET VOLATILITY IN INDIA: SOME FACTS

The increased integration of India and global equity markets may partly be attributable to international investors since India, along with the Asian emerging markets, has become a favourite destination of such investors, who constantly switch their investments from one equity market to another. Foreign institutional investors (FIIs) invest in different markets based on their perception of the domestic market and available alternatives at different points of time. The consequent allocation of funds leads to a degree of synthesis between markets, which results in more integration. With the opening up of the financial sector in India, FII flows have increased substantially to the Indian economy. Portfolio investment has increased from a meagre $6 million in 1990/91 to a substantial $27,271 million in 2007/08. Since such flows are extremely volatile, grave concern is expressed by policy makers and practitioners.

There is mixed evidence regarding the role of such investors in increasing volatility in domestic markets. Some studies find that foreign investors do not have a destabilizing impact on stock prices, e.g. Choe and others (1999), Kim and Wei (1999) with Korean data and Froot and others (2001) based on data from 44 countries. Conversely, there exists evidence that foreign investors do cause higher volatility in the market compared to domestic investors (Jo, 2002),[5] and that stocks in which foreign investors mainly trade, experience higher volatility compared to those in which

[5] They used data from the Korean stock markets, where data are available for different categories of traders.

they do not show much interest (Bae and others, 2002).[6] These studies also show that volatility caused by FII jumped significantly at the time of the crises.

The data on Indian equity market suggest that volatility, measured in terms of standard deviation of returns, has decreased over the past decade (see table 1). Gordon and Gupta (2003) made an observation that the volatility of portfolio flows into India was small in comparison to other emerging markets from 1998 to 2000.[7] While the co-efficient of variation for such flows in India was 1.58, the corresponding figures for Brazil, Chile, the Philippines, the Republic of Korea and Thailand stood at 2.14, 1.94, 1.79, 1.82 and 25.07 respectively. According to the Securities and Exchange Board of India (SEBI) Handbook of Statistics on the Indian Securities Market 2009, volatility in the market index declined from 3.33 in 1992 to 1.1 in 2005[8] and is now comparable to the volatility of stock market indices in the United Kingdom and the United States, as well as other advanced and emerging countries (see table 2). There are studies that examined the volatility of stock markets and foreign institutional investments in the Indian equity market as well. For example, foreign institutional investments and stock market returns in India exhibit quite high volatility with regard to both extent and duration. The evidence suggests that their volatility is interrelated (Coondoo and Mukherjee, 2004).

Whether the volatility of other markets affects the Indian market or not is an issue that cannot be ignored and therefore must be examined properly.

Table 1. BSE Sensex volatility

Year	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Sensex Volatility[a]	2.3	1.83	1.72	–	1.5	1.01	1.35	1.48	1.03	1.75	1.93	2.8

Source: SEBI Handbook of Statistics on the Indian Securities Market 2009.

Note: [a] sd of daily returns.

[6] They analyze data from the Standard & Poor's (formerly the IFC) Emerging Markets Database (EMDB), which covers more than 2,000 stocks from 45 emerging markets.

[7] They have used the quarterly data for 17 emerging markets and measured volatility in terms of co-efficient of variation.

[8] Though there is an increase in volatility for the past two years, this may be attributable to the global crises and it should be noted that this increase in volatility has also occurred in other markets as well.

Table 2. Return and volatility for some world stock indexes

Year	United States of America		United Kingdom		Hong Kong, China		Singapore		Japan		India	
	(DJIA)		(FTSE 100)		(HSI)		(STI)		(NKY)		(BSE Sensex)	
	Return	Volatility	Return	Volatility	Return	Volatility	Return	Volatility	Return	Volatility	Return	Volatility
1992	0.0	0.6	0.1	1.0	0.1	1.4	0	0.9	NA	NA	0.1	3.3
1995	0.1	0.5	0.1	0.6	0.1	1.3	0	1	0	1.2	-0.2	1.3
2000	0	1.4	0	1.2	-0.1	2	-0.1	1.5	-0.1	1.4	-0.1	2.2
2001	-0.1	1.4	-0.1	1.4	-0.1	1.8	-0.1	1.5	-0.1	1.6	-0.1	1.7
2002	0.1	1.6	-0.1	1.7	-0.1	1.2	-0.1	1	-0.1	1.4	0	1.1
2003	0.1	1.1	0.1	1.2	-0.1	1.1	0.1	1.2	0.1	1.4	0.2	1.2
2004	0	0.7	0	0.7	0	1	0.1	0.8	0	1	0	1.6
2005	0	0.7	0.1	0.6	0	0.7	0.1	0.6	0.1	0.8	0.1	1.1
2006	0.1	0.6	0	0.8	0.1	0.9	0.1	0.9	0	1.3	0.2	1.6
2007	0	0.9	0.2	1.1	0.1	1.7	0.1	1.4	-0.1	1.2	0.2	1.5
2008	-0.2	2.6	-0.2	2.4	-0.2	3	-0.2	2.2	-0.2	2.9	-0.2	2.8
2009	-0.1	2.6	-0.1	2.4	0	3.2	0	2.4	-0.1	3	0	3

Source: SEBI Handbook of Statistics on the Indian Securities Market 2009.

III. DATA AND METHODOLOGY

In this paper, the issue of whether the volatility of stock returns in India is significantly influenced by the stock market volatility of developed and emerging markets is analysed. BSE Sensex is considered to be the representative of the Indian equity market. Among other markets studied here are the three developed markets: Japan, the United Kingdom and the United States. As India is getting more integrated through the FII route, some international investors' favourite destinations in the Asia-Pacific region are also considered. These are the Republic of Korea, Singapore and Hong Kong, China. The stock indexes used for the study are the most important benchmark index for each country.

The Indian BSE Sensex is regarded as the pulse of the Indian stock market. Sensex is a free-float market capitalization[9] based index estimated from a basket of 30 constituent stocks, representing a sample of large, liquid and representative companies. The constituent stocks are from a wide range of sectors such as Auto, Banking, Cement, Energy, Information and Entertainment, Oil and Gas, and

[9] Over the past few years, there has been a trend among index providers to consider the amount of shares that are actually available in the market (free-float shares), rather than the official shares outstanding, for use in calculating a company's market capitalization weighting in an index. This helps to reflect the investability of the index.

Pharmaceuticals, to name just a few. The Dow Jones Industrial Average (DJIA) in the United States is included in the study. The DJIA is one of the most closely-watched benchmark indices tracking targeted stock market activity and consists of 30 stocks. Also included in this study is the Financial Times Stock Exchange (FTSE) of the United Kingdom with an index of the 100 most highly capitalised companies listed on the London Stock Exchange. It is by far the most widely used stock market indicator in the United Kingdom, representing about 80 per cent of the market capitalisation of the whole London Stock Exchange.

Within the Asian markets, Japan, the Republic of Korea, Singapore and Hong Kong, China are parts of this study. In Japan, the Nikkei Stock Average is considered to be the most widely watched index of stock market activity. Its 225 components are among the most actively traded issues on the first section of the Tokyo Stock Exchange (TSE). The mix of components is rebalanced from time to time to assure that all issues in the index are both highly liquid and representatives of Japan's industrial structure. The market capitalization based index, the Korea Composite Stock Price Index (KOSPI), measures changes in the share prices of companies quoted on the Korea Stock Exchange (KSE). The index includes all companies listed on the KSE except for bond-type preferred stocks and newly listed stocks. The Straits Times Index (STI), which is compiled by the Straits Times Newspaper of Singapore, is a modified market capitalization-weighted index comprising of 55 of the most heavily weighted and active stocks traded on the Singapore Exchange (SGX). The Hang Seng Index is a capitalization-weighted stock market index in the Stock Exchange of Hong Kong, China (SEHK) and is used to record and monitor daily changes of the 33 largest companies of the Hong Kong, China stock market, drawn from four industry groupings forming the Finance, Utilities, Properties, and Commerce and Industry sub-indexes, and accounting for about three quarters of the market value of all stocks traded on the SEHK.

This study uses a daily data set that spans a little more than nine years, from 1 January 1999 to 15 February 2008, and focuses on days on which all the relevant markets were open for trading.[10] The data series of daily closing values of stock indexes were collected from the website finance.yahoo.com. The daily return (close-to-close) is calculated for each of the markets using the formulae: $r_t = \ln(\frac{P_t}{P_{t-1}})$. The market return series are referred to the name of the respective countries where the trading takes place. The plot of all the return variables, viz, India, Japan, USDJ (United States of America Dow Jones Industrial Average), HK (Hong Kong, China), SK

[10] This leads to 2,259 observations.

(Republic of Korea), SING (Singapore), and UK (United Kingdom) are presented in figures 1 to 7. They all show time-varying volatility which indicates that conditional heteroscedasticity should be included in the estimation.

Figure 1. India

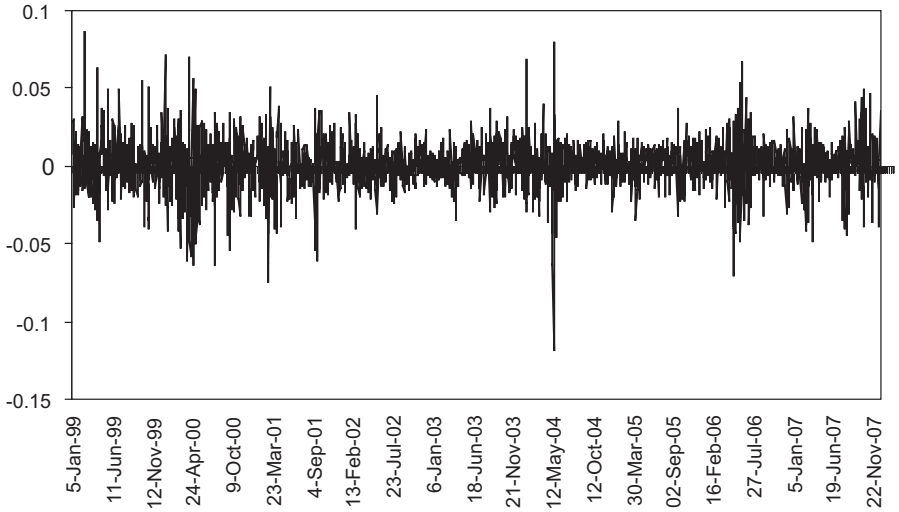


Figure 2. Japan

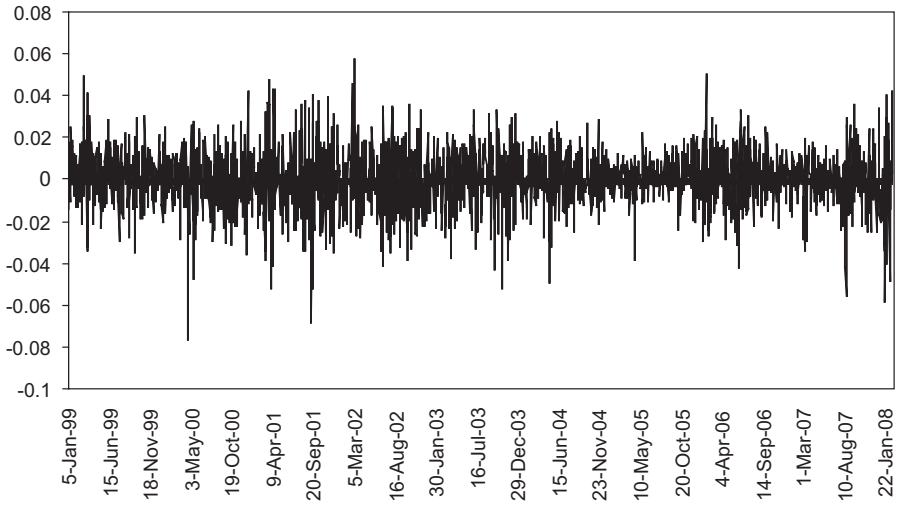


Figure 3. United States

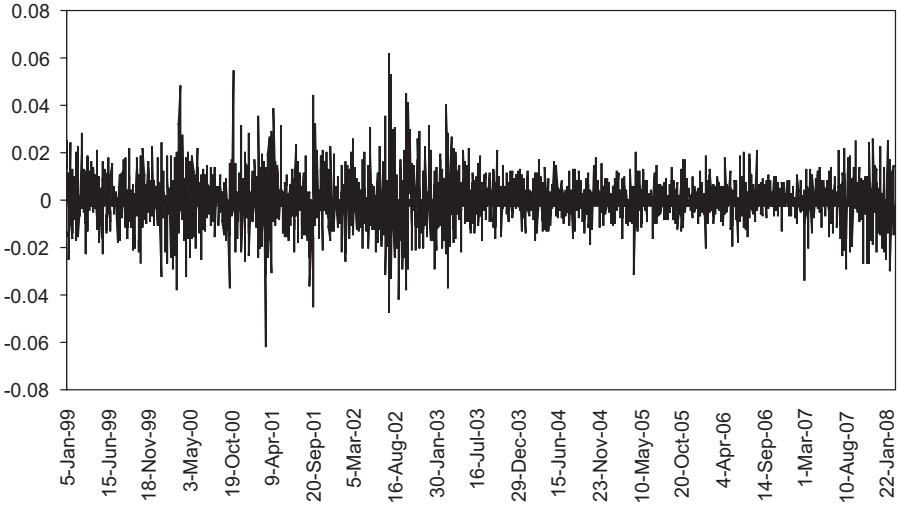


Figure 4. Hong Kong, China

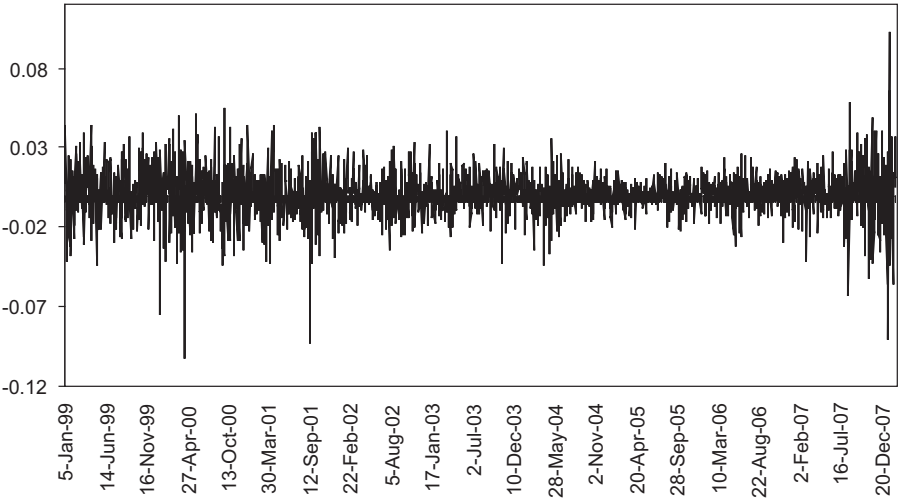


Figure 5. Republic of Korea

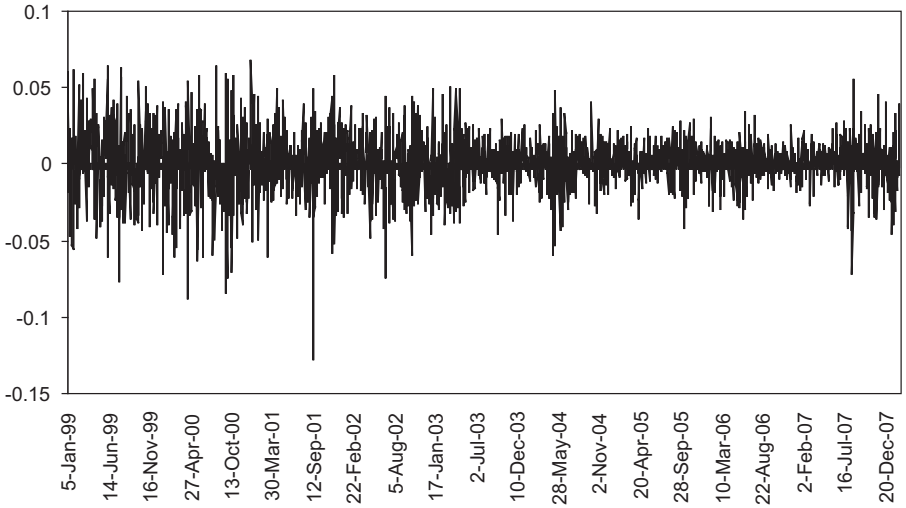


Figure 6. Singapore

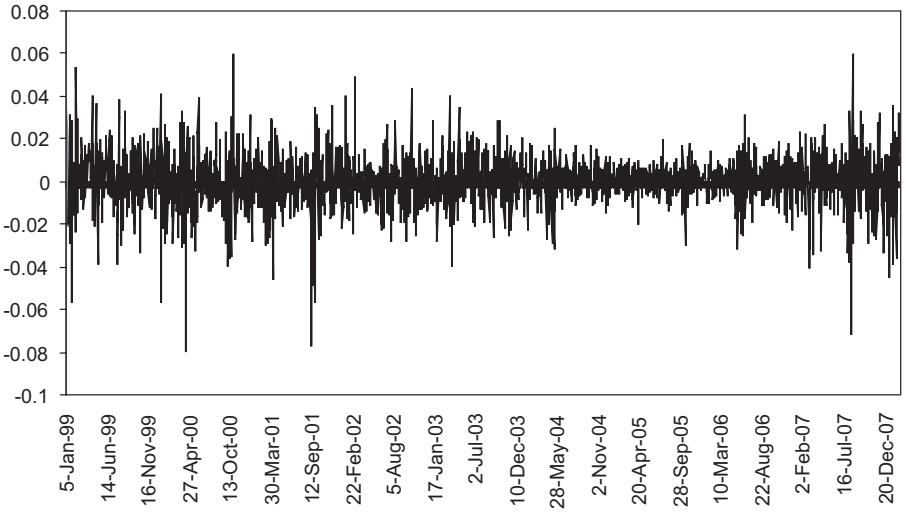
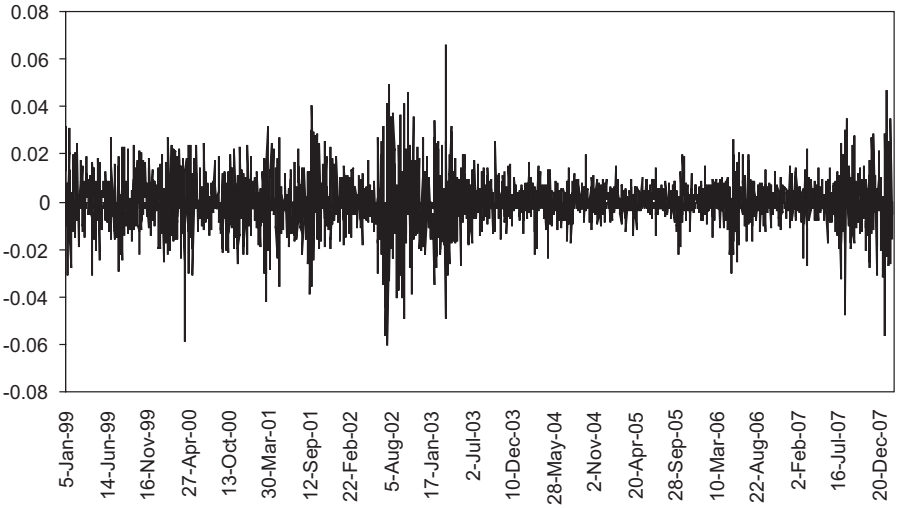


Figure 7. United Kingdom



Next, the stationarity of the return series is checked by augmented Dickey-Fuller as well as Phillips-Perron unit root tests. Then, the empirical analysis is undertaken in the framework of Vector Auto Regression (VAR) for conditional mean and MGARCH for conditional covariance matrix, both estimated simultaneously (Engle and Kroner, 1995; Bauwens and others, 2006). Hence, a VAR model is estimated to reveal the interrelations among the returns of these markets. The covariance of residuals is estimated by a multivariate GARCH. There are different specifications of multivariate GARCH model[11] and a diagonal Baba, Engle, Kraft and Kroner (1990) (DBEKK) model is estimated and used here.

In MGARCH model, the model structure is as follows:

$$\mathbf{r}_t = \boldsymbol{\mu}_t + \boldsymbol{\varepsilon}_t \quad \text{..... (1)}$$

$$E(\mathbf{r}_t | \mathbf{F}_{t-1}) \equiv \boldsymbol{\mu}_t = \boldsymbol{\Phi}_0 + \boldsymbol{\Phi}_1 \mathbf{r}_{t-1} + \boldsymbol{\Phi}_2 \mathbf{r}_{t-2} + \text{.....} + \boldsymbol{\Phi}_p \mathbf{r}_{t-p}, \quad \text{..... (2)}$$

$$\boldsymbol{\varepsilon}_t = \mathbf{H}_t^{1/2} \mathbf{e}_t, \quad \text{..... (3)}$$

[11] There are three commonly used model specifications, viz, constant conditional correlation (CCC) model by Bollerslev (1990), scalar BEKK model by Baba, Engle, Kraft and Kroner (1990) and Engle and Kroner (1995), and dynamic conditional correlation (DCC) model by Engle (2002).

$$E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}'_t \,|\, \mathbf{F}_{t-1}) \equiv \mathbf{H}_t, \quad (4)$$

$$e_t \sim N(0, I), \quad (5)$$

Where $\mathbf{r}_t$ is a $k \times 1$ vector of stock market returns with conditional mean $\boldsymbol{\mu}_t$, k is the number of stock markets considered ($k = 7$ in this study), F_t is the information at time t ($t = 1, 2, \ldots 2259$), $\mathbf{H}_t$ is a $k \times k$ conditional covariance matrix, $\mathbf{e}_t$ is from multivariate normal distribution N(**0**, **I**) and independent & identically distributed (i.i.d).

Now, in a Baba, Engle, Kraft and Kroner (BEKK) model[12] which is a multivariate extension of univariate GARCH model, $\mathbf{H}_t$'s positiveness is guaranteed by

$$\mathbf{H}_t = \boldsymbol{\delta}\,\boldsymbol{\delta}' + \mathbf{A}\boldsymbol{\varepsilon}_{t-1}\,\boldsymbol{\varepsilon}'_{t-1}\mathbf{A}' + \mathbf{B}\mathbf{H}_{t-1}\mathbf{B}' \quad (6)$$

where $\boldsymbol{\delta}$, **A** and **B** are $k \times k$ matrices of parameters to be estimated. Under this framework the conditional covariance matrix is influenced by a long term trend (e.g. $\boldsymbol{\delta}\,\boldsymbol{\delta}'$), the estimated $\mathbf{H}_t$ in the previous period (e.g. $\mathbf{H}_{t-1}$) or the GARCH-term, and the one period lagged residuals (e.g., $\boldsymbol{\varepsilon}_{t-1}\,\boldsymbol{\varepsilon}'_{t-1}$) or the ARCH-term. This specification helps with clarification regarding how the conditional covariance matrix changes according to new information available and how fast the covariance matrix reverts to its long term level (Engle, 2004). The full BEKK model is reduced to a diagonal BEKK model when A and B are defined as diagonal matrices. While the full BEKK specification is able to model the volatility of and co-movement among the k time series more precisely, it becomes difficult to interpret the multiple parameters. As a result, the full BEKK model is primarily used to deal with low dimensional cases, such as the bivariate application in Cotter and Stevenson (2006). In this study, the diagonal BEKK model was used with the seven stock markets.

IV. RESULTS

Before proceeding for the VAR-MGARCH model, the descriptive statistics of the returns series are first presented in table 3. Table 4 shows the correlation among the return variables. It is observed that, in general, Asian markets including India exhibit higher correlation among them when compared to the markets of the United Kingdom or the United States. Table 5 presents the results of the unit root tests. Both the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test suggest that all the return series are stationary.

[12] It was adopted by Baba, Engle, Kraft and Kroner (1991) and Engle and Kroner (1995).

Table 3. Descriptive statistics of the return series

	INDIA	JAPAN	UK	USDJ	HK	SK	SING
Mean	0.00078	0.00001	-0.00001	0.00013	0.00040	0.00047	0.00035
Median	0.00147	0.00029	0.00048	0.00018	0.00057	0.00129	0.00065
Maximum	0.08592	0.05735	0.06533	0.06155	0.10184	0.06782	0.05944
Minimum	-0.11809	-0.07682	-0.06042	-0.06173	-0.10230	-0.12805	-0.07907
Std. Dev.	0.01610	0.01355	0.01159	0.01073	0.01438	0.01864	0.01219
Skewness	-0.34819	-0.25770	-0.16392	0.05033	-0.31094	-0.41321	-0.32111
Kurtosis	7.00888	4.87427	6.18904	5.81688	8.09763	5.81397	7.03098
Jarque-Bera	1 558.34	355.65	967.37	747.82	2 482.31	809.61	1 568.24
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	2 259	2 259	2 259	2 259	2 259	2 259	2 259

Table 4. Correlations of the returns

	INDIA	JAPAN	UK	USDJ	HK	SK	SING
INDIA	1.00						
JAPAN	0.28	1.00					
UK	0.19	0.27	1.00				
USDJ	0.09	0.16	0.45	1.00			
HK	0.38	0.50	0.32	0.13	1.00		
SK	0.30	0.48	0.26	0.12	0.54	1.00	
SING	0.34	0.44	0.34	0.17	0.61	0.50	1.00

Table 5. Unit root tests

	INDIA	UK	HK	SK	JAPAN	SING	USDJ
ADF-stat (level)	-27.36	-26.2174	-27.5555	-24.03853	-27.812	-26.0874	-24.1922
PP-stat	-44.015	-49.7197	-46.3387	-44.74084	-47.528	-44.5864	-48.7679
5 per cent Critical Value	-2.863	-1.940	-1.940	-1.940	-1.940	-1.940	-1.940

Note: The equation does not include intercept or trend for any of the series except India. For India it includes intercept only.

Next, the joint VAR-MGARCH model is simultaneously estimated. For specification of VAR, the order of the model is chosen according to the Akaike Information Criteria and the Schwarz Criteria, the values of which are shown in table 6. The lags 1, 2 and 3 are only taken into consideration because it is unlikely that the return in one market is following the return of the other markets more than three days back. The minimum value of the information criteria suggests that the VAR(1) model is the appropriate one. The estimation of diagonal BEKK (1,1) model is performed by the BHHH method prescribed by Berndt and others (1974). Here the $\delta\delta'$ is taken as a rank one matrix. The estimated co-efficients of this joint VAR (1) – BEKK (1,1) model are presented in table 7, panels A and B.

From table 7, it is observed that the Indian market return is significantly influenced by not only its own past returns, but also those of others markets. The United States and the Republic of Korea are shown to exert positive influence while Hong Kong, China shows a negative influence. The positive co-efficients may be due to a feel-good-factor generated by the increase in returns in the developed markets like the United States and the Republic of Korea. The negative co-efficient with Hong Kong, China can possibly be explained through the activities of international investors. As both India and Hong Kong, China are preferred destinations of such investors, if the Hong Kong, China market return increases, the investors withdraw from India and invest there, resulting in a decline in the return in India. However, more interesting is the evidence that the past returns of the Indian market also have a positive and statistically significant impact on returns of Japan, the Republic of Korea, Singapore and Hong Kong, China.

Panel B of table 7 below shows the conditional variance matrix GARCH with $M = \delta\delta'$ as constant co-efficient, specified as a rank one matrix in this model, A1 as the co-efficient matrix for the ARCH term and B1 as the co-efficient matrix of the GARCH term (see equation 6). All the co-efficients are significant at 5 per cent as well as 1 per cent levels of significance, indicating strong ARCH and GARCH effects of volatility in each of the markets. This implies that significant spillover of volatility from its own past values exists and that the persistence of such volatility is very high for all the markets, including India.

Table 6. Choice of lag for estimation of VAR

	VAR (1)	VAR (2)	VAR (3)
Akaike Information Criteria	**57 062.47**	57 154.22	57 197.92
Schwarz Criteria	**57 062.65**	57 154.57	57 198.43

Table 7. Joint VAR (1) – diagonal BEKK (1,1) model

Panel A: Mean Equation estimated as VAR (1)

	INDIA	JAPAN	UK	USDJ	HK	SK	SING
INDIA (-1)	0.075*	0.059*	0.017	0.004	0.036*	0.067*	0.059*
p-value	0.000	0.000	0.122	0.761	0.010	0.001	0.000
JAPAN (-1)	-0.01599	-0.093*	-0.009	-0.0229	-0.112*	-0.124*	-0.055*
p-value	0.510	0.000	0.602	0.162	0.000	0.000	0.002
UK (-1)	0.039	0.175*	-0.204*	0.031**	0.129*	0.093*	0.062*
p-value	0.125	0.000	0.000	0.096	0.000	0.002	0.002
USDJ (-1)	0.187*	0.362*	0.302*	-0.0569*	0.382*	0.463*	0.325*
p-value	0.000	0.000	0.000	0.006	0.000	0.000	0.000
HK (-1)	-0.043	0.011	-0.007	-0.015	-0.023	0.012	-0.024
p-value	0.106	0.628	0.709	0.403	0.367	0.687	0.274
SK (-1)	0.035**	-0.004	0.003	0.037**	0.013	0.019	0.001
p-value	0.060	0.770	0.797	0.007	0.408	0.360	0.960
SING (-1)	0.025	0.029	-0.012	-0.026	0.038	0.022	-0.021
p-value	0.403	0.175	0.527	0.130	0.126	0.537	0.376
C	0.001066*	0.00004	0.00014	0.000379*	0.000458*	0.00058*	0.000375*
p-value	0.000	0.867	0.361	0.012	0.026	0.048	0.039
Adj. R-squared	0.04	0.13	0.09	0.00	0.17	0.12	0.11

Panel B: Transformed variance co-efficients with covariance specification as BEKK

$$H_t = \delta\,\delta' + A\,\varepsilon_{t-1}\,\varepsilon_{t-1}'\,A' + B H_{t-1}\,B'$$

	INDIA	JAPAN	UK	USDJ	HK	SK	SING
INDIA	0.0000089*						
p-value	0						
JAPAN	0.0000011*	0.0000001*					
p-value	0	0.0001					
UK	0.0000006*	0.0000001*	0.00000004*				
p-value	0	0.0003	0.0247				
USDJ	0.0000002**	0.00000003*	0.000000	0.000000			
p-value	0.0778	0.0844	0.13	0.3675			
HK	0.0000012*	0.0000002*	0.00000001*	0.00000003**	0.0000002*		
p-value	0	0	0.0003	0.0876	0.0001		
SK	0.000002*	0.0000002*	0.0000001*	0.00000004**	0.0000002*	0.0000004*	
p-value	0	0	0.0001	0.0812	0	0	
SING	0.0000001*	0.0000001*	0.0000001*	0.00000002**	0.0000001*	0.0000002*	0.0000001*
p-value	0	0	0.0006	0.095	0	0	0.0003
A1	0.261911*	0.128444*	0.23215*	0.153515*	0.142866*	0.109547*	0.161099*
p-value	0	0	0	0	0	0	0
B1	0.947255*	0.992158*	0.976336*	0.989195*	0.990443*	0.993438*	0.988101*
p-value	0	0	0	0	0	0	0

Notes: $\delta\,\delta'$ = M is a rank one matrix

Estimation method: ARCH maximum likelihood (BHHH); Convergence achieved after 66 iterations.

* significant at 5%, ** significant at 10%.

The conditional variance plots of each return series are presented in figure 8. The conditional volatility for India shows continuous ups and downs with some sharp increases in a few instances. The conditional volatilities of Japan, the Republic of Korea, Singapore and Hong Kong, China show a perceptible declining trend over the sample period considered.

Since the main concern of the study is to find the relationship among the volatility of returns in the seven stock markets, the bi-variate conditional correlation obtained from the model must be studied. Figure 9 presents figures showing a conditional correlation between India and other stock markets. It should be noted that in most cases, the conditional correlations are not constant, but time-varying. In all the figures except those of the USDJ, it is observed that the correlation of the Indian market return with that of other markets has a perceptible positive trend, very distinct in cases of Japan, Singapore, the United Kingdom, the Republic of Korea and Hong Kong, China. The correlation between India and Japan has consistently increased over the sample period. This clearly indicates that volatility spillover does take place between Indian market return and all the Asian majors included in the study, with Japan being the most significant. However, volatility spillover from/to the United States is not that strong.

Figure 10 displays the plot of residuals from the estimated model. It is quite evident from the plot that the residuals corresponding to each of the return series are stationary.

V. CONCLUSION

This paper explores the relationship between equity market volatility in India and that in other specified markets. Based on a daily data set from nearly a decade, such associations are analysed by estimating a joint VAR (1)-MGARCH (1,1) model. The uniqueness of this paper lies in its method of combining the VAR and multivariate GARCH models to explore the possibility of volatility transmission to India from markets like Japan, the United Kingdom and the United States, as well as emerging markets such as Singapore, the Republic of Korea and Hong Kong, China.

The analysis yields some very interesting findings: (a) Indian market return is significantly influenced by the past returns of its own and also of the Republic of Korea and of the United States positively and that of Hong Kong, China negatively; (b) there is evidence that the past returns of the Indian market have also significantly impacted the returns of Japan, the Republic of Korea, Singapore and Hong Kong, China. This can be linked to the findings of Mukherjee and Bose (2008) that were based on an older data set; (c) the Indian return volatility spillovers from/to Japan as well as other Asian markets are further confirmed by the time-varying trend of

Figure 8. Conditional Variance

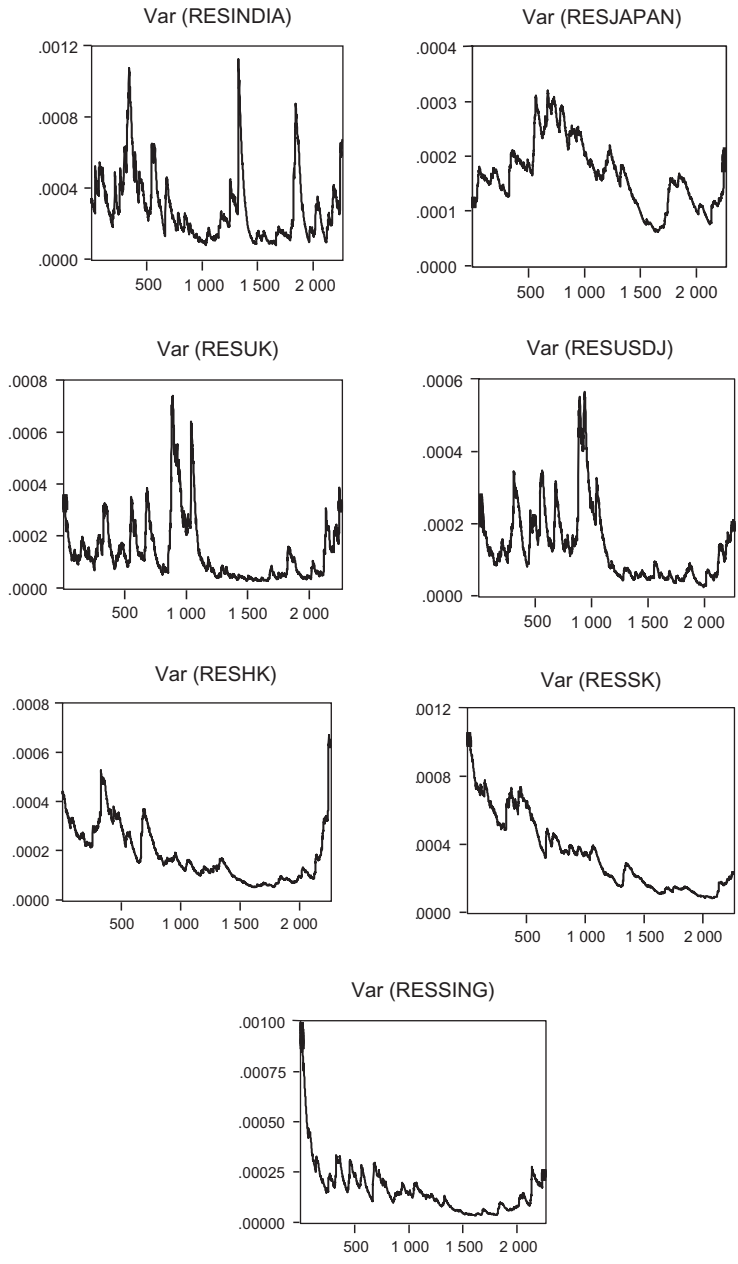


Figure 9. Conditional correlation between India and other markets

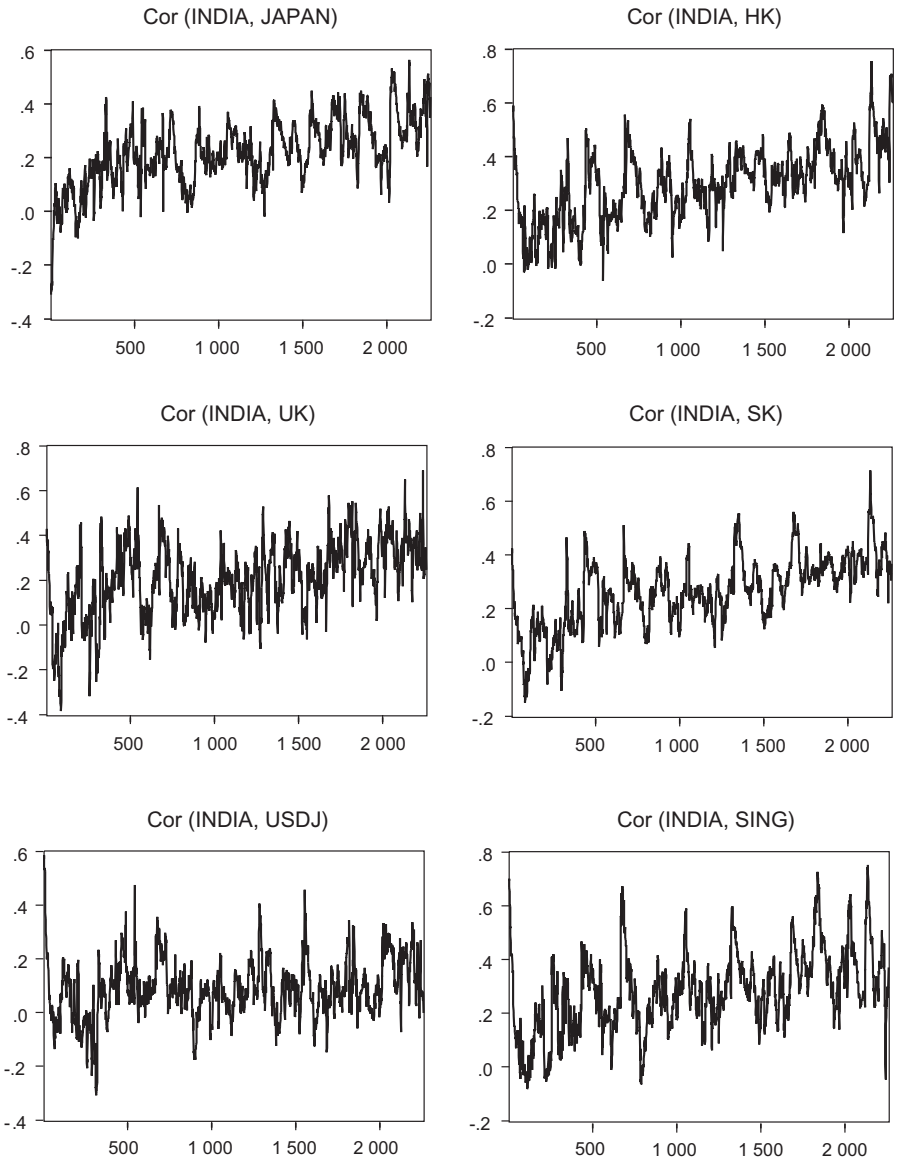
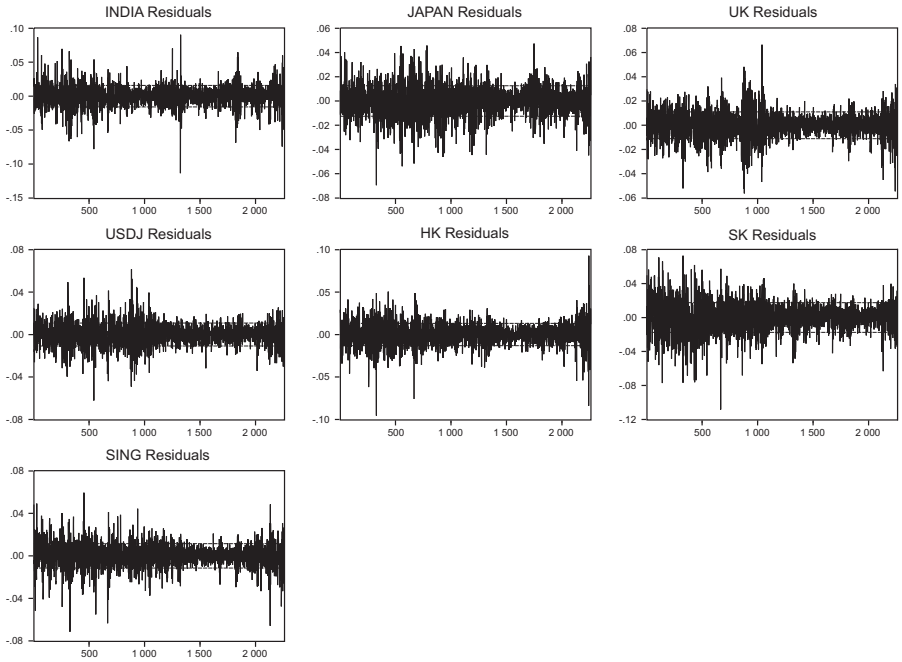


Figure 10. Plots of residuals



conditional correlations. The correlations show a clear positive trend over time, implying that they have increased over the years; and (d) unlike other Asian markets, the volatility in the Indian equity market does not exhibit any positive or negative trend in conditional volatility, but has evidenced some spikes over the past nine years.

Evidence suggests that Japan is the leader and has a unique role in the integration of Asian markets (Mukherjee and Bose, 2008). Since it has been observed that returns in the Indian market affect those of Japan, the United Kingdom, the United States, and Hong Kong, China, and that there is evidence of volatility spillovers from/to India to/from the Asian markets, it may not be improbable to consider India as another leader in the integration of capital markets in the Asian region in the near future. India might also have a decisive role in the integration of Asian markets in the future. The increased conditional correlations in the Asian region point towards more future integration of the Indian market with other Asian markets.

From the results shown in this study, there are some policy implications for an emerging market like India, which is yet to achieve the depth and width of a developed market. With international investors investing globally, markets have

become more integrated and their switching of funds between different markets has led to increased volatility in some markets. In India, positive trends in conditional correlation with other markets over the sample period have been observed, indicating more integration. Given the fact that India is also one of the favourite destinations of international investors in this region, it is quite possible that FIIs have contributed to this distinction. Whatever the reasons, there are two policy implications. One is to strengthen the domestic investor base. This is important because stock market participation by the majority of savers in India is quite low. One of the reasons is malpractice (see National Stock Exchange, 2001, in this context). A Securities and Exchange Board of India-National Council of Applied Economic Research (SEBI-NCAER) survey showed that alleged malpractices such as insider trading and low confidence in brokers, sub-brokers, company management and auditors were the main reasons for the lack of domestic savers' confidence in equity markets. Further regulatory authorities would need to look into alleged restrictive practices by FIIs such as the price rigging that has been suggested by Samal (1997). Strengthening the domestic investor base will act as a cushion against the uncertainty created by volatility in the market through the FII route. This may be achieved through the harmonization of corporate governance, accounting and listing, as well as other standard rules and practices followed in other international financial centres.

The second policy implication is keeping a constant watch on FIIs as containing volatility of such flows will contain the market volatility to a great extent. The occasional sudden increases in volatility observed in this study may have some relation to the volatility of foreign investment flows due to sudden withdrawals of funds by international investors. Volatility of portfolio flows is negatively influenced by the depth of domestic stock markets, the size and competitiveness of the domestic banking system and economic growth (Broto and others, 2008). Hence, policies should focus on these areas. For example, provision of better information on corporate and banking accounts will help investors assess the true risks and perhaps reduce herding behaviour, which is very often observed among FIIs.[13] Apart from that, whether or not to impose restrictions[14] on such investors can be considered by policy makers as the two-way volatility linkage implies more vulnerability for the not-very-developed Indian market compared to its developed counterparts.

[13] Batra (2003) researched such behaviour among FIIs investing in India.

[14] For example, Malaysia imposed controls on foreign investment outflows in September 1998. These included, among other measures, limits on investments abroad (prior approval being required), control of offshore markets in the ringgit (residents were previously allowed to borrow ringgit from non-resident banks), and all ringgit earnings had to be held in the domestic currency for a year until conversion was allowed. By February 1999, however, Malaysia had modified the quantitative controls on capital to a price based system by adopting exit taxes.

Finally, if India indeed does have a role to play in the integration of the Asian region, as indicated by this study, then other countries will also have to be aware of the movement and volatility of the Indian market. In addition, there is a possible extension of this study. One can examine the route through which such volatility transmission is taking place. Whether the transmission is due primarily to international investors or to other reasons, further investigation is required, as this becomes important for policy makers.

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