Price and Volatility Spillovers across North American, European and Asian Stock Markets: With Special Focus on Indian Stock Market

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Abstract

This paper investigates interdependence of fifteen world indices including an Indian market index in terms of return and volatility spillover effect. Interdependence of Indian stock market with other fourteen world markets in terms of long run integration, short run dependence (return spillover) and volatility spillover are investigated. These markets are that of Canada, China, France, Germany, Hong-Kong, Indonesia, Japan, Korea, Malaysia, Pakistan, Singapore, Taiwan, United Kingdom and United States. Long run and short run integration are examined through Johansen cointegration techniques and Granger causality test respectively. Vector autoregressive model (VAR 15) is used to estimate the conditional return spillover among these indices in which all fifteen indices are considered together. The effect of same day return in explaining the return spillover is also modeled using univariate models. Volatility spillover is estimated through AR-GARCH in which residuals from the index return is used as explanatory variable in GARCH equation. Return and volatility spillover between Indian and other markets are modeled through bivariate VAR and multivariate GARCH (BEKK) model respectively. It is found that there is greater regional influence among Asian markets in return and volatility than with European and US. Japanese market, which is first to open, is affected by US and European markets only and affects most of the Asian Markets. Also, high degree of correlation among European indices namely FTSE, CAC and DAX is observed. US market is influenced by both Asian and European markets. Specific to Indian context, it is found that Indian market is not cointegrated with rest of the world except Indonesia. This may provide diversification benefits for potential investors. However, strong short run interdependence is found between Indian markets and most of the other markets. Indian and other markets like US, Japanese, Korean, and Canadian positively affect each others' conditional returns significantly. Indian market also has significant effect on Malaysia, Pakistan, and Singapore return. This study found that there is significant positive volatility spillover from other markets to Indian market, mainly from Hong Kong, Korean, Japanese, Singapore and US market. Indian market affects negatively the volatility of US and Pakistan. It is interesting to note that Chinese and Pakistan markets are less integrated with other Asian, European and US markets.

Keywords: Return Spillover, Volatility spillover, VAR (15), BEKK, Emerging market, Cointegration, Granger causality

JEL Classification: G15; C32

1. Introduction

Currently, the financial markets are witnessing liberalized capital movements, financial reforms, advances in computer technology and information processing. This trend is evident in both developed and developing countries. These factors have reduced the isolation of domestic markets and increased their ability to react promptly to news and shocks originating from the rest of the world. This indicates that the linkages between stock markets around the world may have grown stronger. This paper is based on a study of empirical nature investigating these linkages. International linkage of emerging markets has major implications for emerging markets and for international diversification. Strong linkage reduces the insulation of emerging markets from any global shock whereas weak market linkage offers potential gains from international diversifications.

Modern portfolio theory says that gains from international portfolio diversification are inversely related to the correlation between the equity returns. Investors hold various securities in the expectation of achieving a reduction in risk via diversification. In the mean variance framework, correlation is the measure of co-movement in returns. Errunza (1977) demonstrated the advantage of international diversification based on low correlation between the equity markets. Later, Kasa (1992) argued that benefits from international diversification based on low correlations may be overestimated. If the investor has a long term investment horizon and markets reach the long run equilibrium, the strategy based on correlation will not work. In other words, any benefit accrued from diversification will be eradicated in the long run. This implies that correlations are time varying and investors need a more accurate measure of international stock market interdependence. Hence, the researchers have suggested the use of co-integration test for finding the long run dependence between the markets. Also, based on co-integration and causality analysis, the investment strategy of the investors and traders can be explored. Furthermore, understanding short run interdependence in returns and volatility across different markets adds to insights related to diversification and hedging strategies.

Information transmission across markets has been widely studied. Most of the studies focus on the long term interdependence and causality among stock markets, in order to find long-term or short term correlation among these markets (Eun and Shim, 1989; Nath and Verma, 2003; and Constantinou, Kazandjian, Kouretas and Tahmazian, 2005). However, the information transmission across markets might not be only through mean returns but also through volatility (Bekaert and Harvey (1997), Ng (2000), Baele (2002), Christiansen (2003), and Worthington and Higgs (2004)). Most of the results indicate the importance of US market in transmitting return and volatility to other developed and emerging markets. However in Asian context, the Japanese market plays the role of a leading market. It has been argued that if two markets are integrated then any external shock in one market will not only affect the return but also volatility in other markets. Understanding volatility spillover across markets is important because it is a measurement of risk and helps in estimating the risk of internationally diversified portfolio, in executing hedging strategy and asset allocation, and also in devising policies related to capital inflow in the market.

Over the past fifteen years there has been a growing interest among the portfolio managers in the emerging capital markets as they are expected to provide higher asset returns compared to the

developed markets. However, with opening of the economies, the increasing integration between the emerging and the developed markets has led to information and sentiment spillover from one market to another. Also, the listing of stocks at dual or multiple stock exchanges all over the globe may have also added to integration of markets (Bennett and Keller, 1988).

The emerging Indian financial markets have also attracted considerable investment in last decades. Indian capital market is still evolving and many important reforms related to institution, processes and instruments have taken place. The major reforms in processes and services such as dematerialized trading of securities, the reforms in the trading system such as electronic trading, central counterparty, rolling settlement, clearing & settlement mechanism, and the reforms in the carry forward & margin trading system have been initiated with the objectives of increasing the width and depth of the Indian capital market. In the year 2000, various new instrument like index futures and option were introduced. Beginning 1991, when economic and financial sector reforms were initiated, the integration of Indian stock market with other markets has accelerated. In this phase, the policies related to the inflow of foreign funds with entry of foreign institutional investors (FII), investment norms for non-resident Indians (NRIs), persons of Indian origin (PIOs), overseas corporate bodies (OCBs), global depository receipt (GDR), American depository receipt (ADR) and foreign currency convertible bond (FCCB) have been liberalized. FIIs hold about 25 percent of market capitalization of the large Indian stock (around $1.3 trillion), if cumulative dividends that are rolled over are included (Singh, 2007). However, around 50 percent of FII flows have been via participatory notes (PNs). FII investments in the Indian equity market have increased its dependence on other financial markets. Some of the Indian listed companies have issued instruments such as American Depository Receipts (ADR) and Global Depository Receipts (GDR) and have got their equity shares listed on the US bourses such as NASDAQ and NYSE and on London. In October 2007, to moderate and create more transparency in the capital flow in the Indian market, offshore derivative instruments, including participatory notes (PNs), equity linked notes and capped return notes - all used by foreign institutional investors (FIIs) to invest in Indian stocks, were banned. This resulted in lower investment by portfolio investors like hedge funds and immediate reaction of the market.

In Indian context, there has been relatively few studies exploring linkages of Indian markets with international other markets. These are limited to studying linkages with few markets namely US and Japanese markets. The informational linkages between the US and Japanese markets with the Indian market has been studied by Rao and Naik (1990), Kumar and Mukhopadhyay (2002), Hansda and Ray (2002, 2003), Nair and Ramanathan (2002), Nath and Verma 2003, Kaur (2004), Mukherjee and Mishra (2006) and Kiran and Mukhopadhyay (2007). Most of the studies demonstrate the dominance of US and Japan market and information flows from these markets to India. Methodologically, most of the works are limited to cointegration, causality test or univariate GARCH. Application of multivariate GARCH models is limited to investigation of volatility spillover.

Previous works in this area, especially in context of emerging Asian markets, focused on the impact of developed markets on emerging Asian markets, and on intra-regional interdependencies across emerging markets, while controlling for the impact of developed markets. Methodologically, same day effect (even when their opening and closing times are significantly different) has been usually ignored in return and volatility spillover estimation.

Estimation of return and volatility spillover through Vector Autoregressive (VAR) and VAR-BEKK models are limited to two or three variables (Liu and Pan, 1997; Christofi and Pericli, 1999; In et al., 2001). In case of more markets, the CCF test developed by Cheung and Ng (1996) has been widely used (Fujii, 2005; Gebka and Serwa, 2007) for causal relationship across markets ignoring partial effects of other markets. Specifically for Indian market, there are very limited studies in the area of information transmission and are limited to informational linkages of Indian markets with the US and Japanese markets (Kumar and Mukhopadhyay, 2002; Hansda and Ray, 2002; Nair and Ramanathan, 2002; Nath and Verma, 2003; Kaur, 2004; Mukherjee and Mishra, 2006; and Kiran and Mukhopadhyay, 2007).

The purpose of this study is to explore the return and volatility spillover effects among Asian (China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Pakistan, Singapore, and Taiwan), European (Germany, France and United Kingdom) and North American (Canada and United States) markets. In this study, lag effect of returns is estimated by VAR model with 15 endogenous variables. The same day effect of markets is captured by AR model in which returns of the markets that open/close before the market under examination, the same day returns are used as explanatory variable and those which open/close after, the one day lag returns are used. The Volatility spillover is estimated using two steps AR-GARCH model (Liu and Pan, 1996) and same day effect is also captured using the same method as used in return spillovers. For Indian market, long-term integration, short-run return spillovers and volatility spillovers are explored using Johansen co-integration, Granger causality test (bivariate VAR) and VAR-BEKK model respectively. A priory, it is expected that there should be higher interdependence of Indian market with Asian markets other developed markets especially the US market. The reasons are increasing trade linkages of Indian economy with these countries, FII flows and dual listing of companies.

The rest of the paper is organized as follows. Section 2 presents the brief literature review of the volatility and return spillover across markets. The data and its descriptive statistics are provided in section 3. Methodology employed for the present study is explained in section 4. Section 5 describes the empirical findings and discussions based on that. Final section gives the summary of the paper along with conclusions.

2. Literature review

Interdependence among international markets has been studied in two broad contexts: interdependence in return (Hilliard, 1979, and Errunza and Losq, 1985) and interdependence in volatility (Hamao et al., 1990; Theodossion and Lee, 1993; Koutmos and Booth, 1995; Liu and Pan, 1997; In et al., 2001; Jang and Sul, 2002; Leong and Felminglam, 2003; Darrat and Benkato, 2003; Cifarelli and Paladino, 2004; Hoti, 2005). Most of the studies have focused on the developed markets especially interdependence among U.S., Japanese and major European markets. Some work, discussed latter has also been done in case of developed Asian and emerging market context in which interrelations among emerging markets (such as East Asia, Latin America, and the Middle East) and the developed equity markets have been studied.

Grubel (1968) studied the gains of international diversification by investigating the co-movement and correlation between different markets from US perspective. Hamao et al. (1990) used

univariate GARCH model and Koutmos and Booth, (1995) used EGARCH model to study return and volatility spillover between New York, Tokoyo and London stock markets. Most of the results indicated the importance of US market in transmitting return and volatility to other developed and emerging markets.

The application of multivariate GARCH model in estimating volatility spillover was initiated by Engle, Ito and Lin (1990), who investigated the intraday volatility spillover between US and Japanese foreign exchange markets. The same model was further applied on various capital markets by various authors (Bekaert and Harvey (1997), Ng (2000), Baele (2002), Christiansen (2003), and Worthington and Higgs (2004)). Karolyi (1995) used multivariate GARCH model to find the short-run interdependence of return and volatility of Toronto and New York stock market. Theodossiou et al. (1997) also used multivariate GARCH approach to investigate stock market returns in the USA, Japan and the UK during 1984 to 1994 and found some statistically significant volatility spillovers form the USA and Japan to the UK. Liu and Pan (1997) studied the volatility spillover among U.S., Japanese and four other Asian stock markets and found that the U.S. market is more influential than the Japanese market in transmitting returns and volatilities to the other four Asian markets. Ng (2000) studied volatility spillovers from Japan and the US to pacific-basin stock markets. Baele (2002) investigated the time-varying nature of the volatility-spillover effects from the US (global effects) and the aggregate European stock markets (regional effects) into individual European stock markets. Christiansen (2003) examined mean and volatility spillover effects from both the US and Europe into the individual European bond markets and found negligible mean-spillover but volatility-spillover effects was substantial. Wongswan (2006) studied the information transmission from the U.S. and Japan to the Korean and Thai equity markets and concluded that there is a large and significant association between developed market and emerging market equity volatility at short time horizons.

In European countries context, many authors examined the effect of introduction of EURO (1st Jan 1999) on European markets linkage and linkage between European and US. Most of the studies found that linkages between European markets increased after EURO (Melle, 2003), however, the linkages between European and US market is not conclusive. Cheung and Westermann (2001) concluded that the spillover did not change between US and European market before and after introduction of EURO. While analyzing volatility spillover between US, UK and Japan market using high frequency data, McAleer (2003) found that volatility spillover took from UK to USA and Japan and from USA to UK. Savva et al. (2004) examined the spillover among US, Germany, London and France market using dynamic correlation framework and found that European markets (only London and German) are affected by US. They also conclude that the correlation across European markets has increased after the introduction of EURO. Bartram et al, (2007) analyzed market linkages among Euro and Non-Euro European countries using a general time-varying copula dependence model. They investigated the impact of the introduction of the Euro on the dependence of equity markets in Europe and found that market dependence within the Euro area increased only for some countries, like France, Germany, Italy, Netherlands and Spain.

In Asian markets context, Bekaert and Harvey (1997) analyzed the volatilities of emerging equity markets and found that in well integrated markets, global factors influence the volatility, whereas local factors affects the segmented emerging markets. In et al. (2001) studied the

volatility transmission among Asian countries during the Asian Financial Crisis period from 1997 to 1998. They found that reciprocal spillover exist between Hong Kong and Korea. Jang and Sul (2002) investigated the co-movement of Asian stock markets before and after the Asian Financial Crisis. They found that the co-movement among the Asian markets increased during the financial crisis period. Similar findings have been reported by Leong and Felmingham (2003). Johnson and Soenen (2002) examined the degree of integration of 12 Asian equity markets with Japan and found that the equity markets of Australia, China, Hong Kong, Malaysia, New Zealand and Singapore are highly integrated with the stock market in Japan. Premaratne and Miyakoshi (2002) examined the magnitude of return and volatility spillovers from Japan and the US to seven Asian equity markets using bivariate EGARCH model and found regional integration among Asian countries than effect of US market on these Asian countries. Bala (2004) investigated the volatility spillover between Singapore and Hong Kong, Japan, the USA and UK. They found high degree of volatility co-movement between the Singapore and Hong Kong, USA, Japan and UK. Worthington and Higgs (2004) found the presence of positive mean and volatility spillovers among nine Asian stock markets. Sang Jin Lee (2007) used bivariate GARCH model and examined the volatility spillover effects across six Asian countries. Author found that there are statistically significant volatility spillover effects within the stock markets of these six countries. Chuang et al. (2007) investigated the volatility spillover among six East Asian markets by using VAR-BEKK framework. They found that the Japanese market is least susceptible to volatility stimuli from other markets, but is however most influential in transmitting volatility to the other East Asian markets.

In Indian context, international linkages have been relatively less studied and have been mostly investigated with US and some developed Asian markets like Japan, Korea etc. Using cross-spectral analysis, Rao and Naik (1990) examined the correlation among US, Japanese, and Indian stock markets and found that the relationship of the Indian market with international markets is poor. They concluded that the poor integration of Indian market with US and Japan is because of heavy controls and restriction on trade and capital flow in Indian market throughout the entire seventies.

Hansda and Ray (2002) examined the interdependence between the BSE/NSE and the Nasdaq/NYSE at aggregate market level. They considered only the technology stocks and found that there exists only unidirectional causality from the Nasdaq/NYSE to BSE/NSE. Hansda and Ray (2003) also studied the price interrelationship between the prices of ten stocks i.e. the stocks, listed simultaneously on the BSE and NSE and the Nasdaq/ NYSE. They used VAR models and found that there is bi-directional causality between the prices of the dually listed stocks. Authors concluded that the markets are efficient in processing and incorporating the pricing information.

Nair and Ramanathan (2002) examined the long run relationship between the US and Indian stock market indexes by using Engle Granger residual based test of cointegration, and Hsiao, Granger and Sims tests of causality and found that there exist a long run relationship between the Nasdaq Composite Index and the NSE Nifty. The direction of causation was from Nasdaq Composite Index to NSE Nifty. Kumar and Mukhopadhyay (2002) examined the return and volatility spillover from Nasdaq to Nifty using daily data from July 1999-June 2001 period. They applied two stage GARCH and ARMA-GARCH model to capture this effect and found that Nifty returns and volatility are significantly affected by the previous day's daytime returns and volatility of Nasdaq composite. Nath and Verma (2003) studied the market indices of India,

Singapore and Taiwan. They found no correlation between these indices. Kaur (2004) studied the return and volatility spillover between India (Sensex and Nifty) and US (NASDAQ and S&P 500) markets by using EGARCH and TGARCH volatility models. She found a mixed evidence of return and volatility spillover between the US and the Indian markets. Mukherjee and Mishra (2006) examined the return and volatility spillover among Indian stock market with that of 12 other developed and emerging Asian countries over the period November 1995 to May 2005. They modeled open-to-close as well as close-to-open return and volatility as GARCH process and found that the Indian open-to-close returns are more related to foreign market return than its close-to-open returns. However, the close-to-open (overnight) volatility of India is more affected by the foreign markets. Kiran and Mukhopadhyay (2007) compared various GARCH models on intraday data of the period July 1999-June 2001 to estimate the volatility spillover from Nasdaq to Nifty and found that there is significant volatility spillover from US to Indian market. They also concluded that the simple ARMA-GARCH model performs better than the more complex MGARCH model.

Most of the studies in Indian markets explore the linkages of Indian market with US and Japan. The integration of Indian market with other Asian market is not adequately explored. Also, studies in this context generally use bivariate VAR or bivariate GARCH model and hence same day information spillover is ignored. Asian, European and North American markets open (close) as different time and if information flows through time, ignoring some important markets and using bivariate model will biased the results. In this paper we consider 15 indices including Indian index and use VAR (15) to estimate the return spillover. The same day effect in returns and volatility spillover are also modeled using AR-GARCH model. In following sections, data used for analysis, methodology, empirical results and conclusions are presented.

3. Descriptive statistics of return on indices

In this study, we investigate the relationship between BSE 30 index (representing Indian market) with 14 other indices of different countries as presented in Table 1. The opening and closing timing of the indices (local and GMT timings) are presented in Figure 1. Opening and closing timings with respect to BSE 30 timing are also presented in Table 2. Daily opening and closing prices of these indices for the period of 1st January 2000 to 22nd February 2008 have been considered. Data of these indices has been taken from yahoo finance site[1]. Only dates for which all the indices have value are taken which results in 1441 data points for closing price series and 1369 values for opening prices.

Daily close-to-close and open-to-open returns of the indices are calculated by taking the logarithm of ratio of price at time 't' and price at time 't-1'. The descriptive statistics of the index returns are presented in Table 3 (a) & 3 (b).

The correlation between BSE 30 close-to-close returns and open-to open returns with other indices are presented in Table 4. A significant correlation is observed between BSE 30 and other indices of the world. The correlation is highest with the Hang Seng Index (Hong Kong) and lowest with SSE Composite Index (China) for close-to-close returns and open-to open returns. On the average the correlation with Asian countries is same as non Asian countries.

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[1] http://finance.yahoo.com/

Table 1: Indices, their Country and Opening and Closing Timings

Index	Country	Local Time		GMT	
		Open	Close	Open	Close
Nikkei 225	Japan	9:00	15:00	0:00	6:00
KOSPI	Korea	9:00	15:00	0:00	6:00
STI	Singapore	9:00	16:00	1:00	8:00
TSEC	Taiwan	9:00	16:00	1:00	8:00
KLSE	Malaysia	9:00	16:00	1:00	8:00
SSE Composite	China	9:30	15:00	1:30	7:00
Hang Seng	Hong Kong	10:00	16:00	2:00	8:00
JSX Composite	Indonesia	10:30	14:30	2:30	7:30
BSE 30	India	9:55	16.15	4:25	10:00
KSE 100	Pakistan	9:30	15:30	4:30	10:30
FTSE 100	United Kingdom	8:00	16:20	8:00	16:20
CAC 40	France	9:00	17:35	8:00	16:35
DAX 30	Germany	9:00	17:35	8:00	16:35
NASDAQ	United States	9:30	16:00	14:30	21:00
S&P/TSX 60	Canada	9:30	16:00	15:30	22:00

Table 2: Stock Market Timings of Various Markets with respect to Indian Market

Index	Opens before BSE 30	Opens after BSE 30 opening but before its closing	Opens after BSE 30 closing	Closes before BSE 30 opens	Closes after BSE 30 opening but before its closing	Closes after BSE 30 Closes
Nikkei 225	YES	NO	NO	NO	YES	NO
KOSPI	YES	NO	NO	NO	YES	NO
STI	NO	YES	NO	NO	NO	YES
TSEC	YES	NO	NO	NO	YES	NO
KLSE	NO	YES	NO	NO	NO	YES
SSE Composite	YES	NO	NO	NO	YES	NO
Hang Seng	YES	NO	NO	NO	YES	NO
JSX Composite	YES	NO	NO	NO	NO	YES
KSE 100	NO	YES	NO	NO	NO	YES
FTSE 100	NO	YES	NO	NO	NO	YES
CAC 40	NO	YES	NO	NO	NO	YES
DAX 30	NO	YES	NO	NO	NO	YES
NASDAQ	NO	NO	YES	YES	NO	NO
S&P/TSX 60	NO	NO	YES	YES	NO	NO
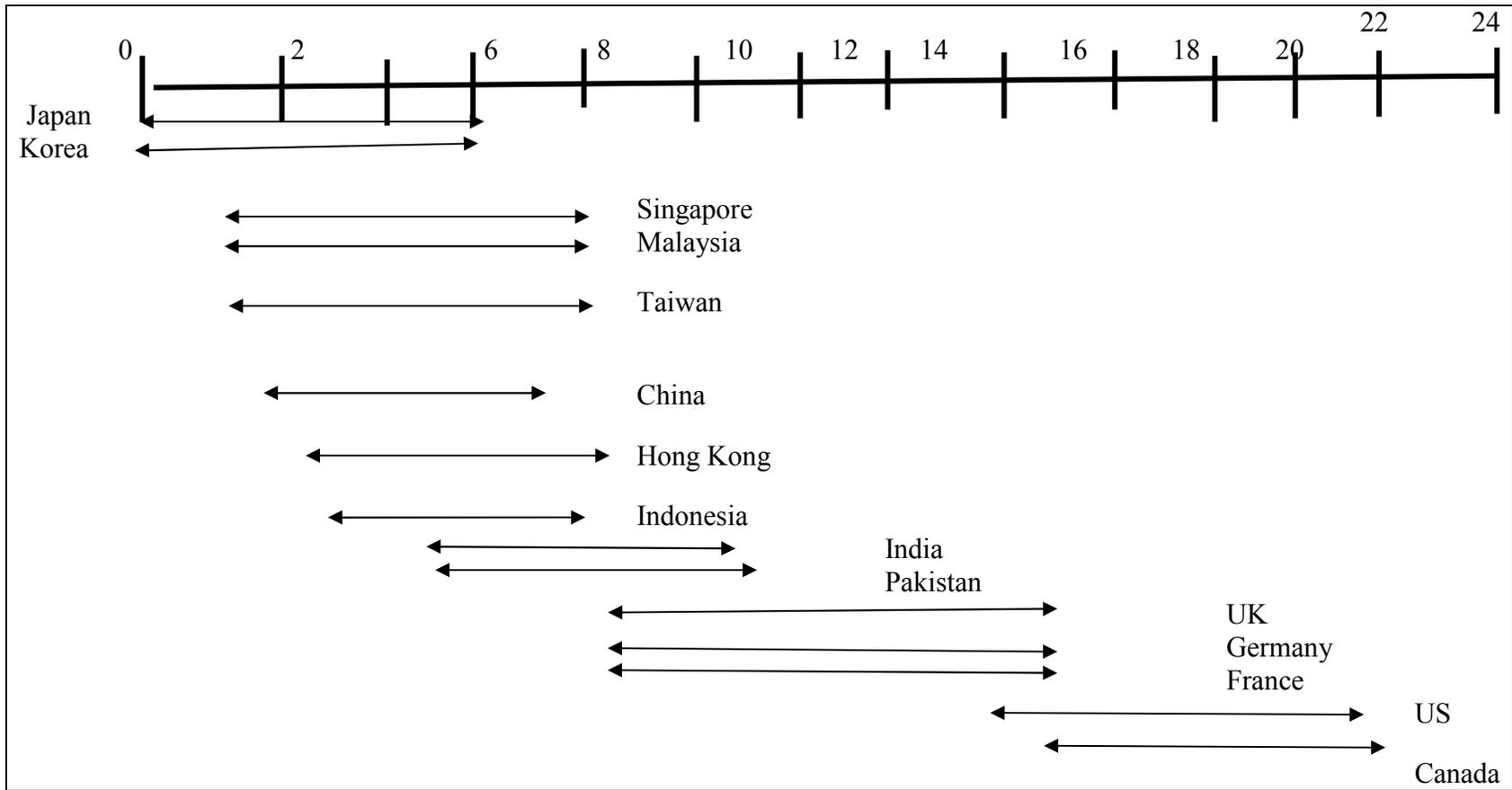
Figure 1: Stock Market Timings of Various Markets

Table 3 (a): Descriptive Statistics of Index Return for Closing Prices

Index	Mean	Std Dev	Minimum	Maximum	Skewness	Kurtosis
Nikkei 225	-0.00375	1.11511	-5.22584	4.58401	-0.05766	1.96982
KLSE	0.0354	0.68912	-3.07115	4.13949	0.19712	3.38585
KOSPI	0.04412	1.42382	-7.44139	6.45045	-0.20408	3.45553
STI	0.01514	0.91303	-3.50782	3.99899	-0.0019	2.061
TSEC	0.02994	1.23578	-6.67865	6.17205	0.15381	3.60852
Hang Seng	0.01809	1.07198	-5.9637	6.50886	0.05558	3.62621
JSX Composite	0.11692	1.07528	-4.43238	4.43328	0.08383	1.87084
SSE Composite	0.03759	1.28088	-9.75001	6.8896	-0.37493	5.16427
BSE 30	0.05147	1.25512	-6.29856	7.9311	-0.04817	4.24851
KSE 100	0.08548	1.20459	-6.04175	4.62839	-0.51681	3.16588
CAC 40	-0.01771	1.14455	-5.54915	6.12981	-0.08404	3.33876
DAX 30	-0.03314	1.27327	-5.69036	6.84168	-0.07224	3.44775
FTSE 100	-0.02256	0.92816	-4.91812	4.87763	-0.40345	4.15069
NASDAQ	-0.03497	1.54909	-7.39031	9.96364	0.19229	5.06299
S&P/TSX 60	-0.00644	0.96318	-8.0792	4.51277	-0.61769	7.1846

Table 3 (b): Descriptive Statistics of Index Return for Opening Prices

Index	Mean	Std Dev	Minimum	Maximum	Skewness	Kurtosis
Nikkei 225	-0.02891	1.09933	-6.35509	6.34547	0.03168	3.12289
KOSPI	0.02348	1.50342	-7.25245	8.11447	-0.28908	2.82846
STI	-0.00618	1.0037	-4.78051	5.5686	0.02003	3.35668
TSEC	0.00202	1.41118	-9.48549	7.2397	-0.42077	4.91149
KLSE	0.02299	0.70614	-3.85846	3.04462	0.06134	3.08825
SSE Composite	0.04706	1.47909	-10.3761	7.94986	-0.38233	5.69499
Hang Seng	0.00165	1.1256	-4.18923	5.22604	0.11658	2.51087
JSX Composite	0.07137	1.1436	-7.43662	5.3591	-0.46524	4.28333
BSE 30	0.03877	1.43603	-9.89856	8.30918	-0.42416	6.19699
KSE 100	0.06823	1.35867	-7.14923	6.41083	-0.7542	4.7938
FTSE 100	-0.02919	0.94923	-5.58878	4.87763	-0.36798	5.0701
CAC 40	-0.00655	1.20167	-5.66272	7.17382	0.19186	5.1941
DAX 30	-0.00085	1.25899	-6.50464	7.27009	-0.08521	4.89016
Nikkei 225	-0.02891	1.09933	-6.35509	6.34547	0.03168	3.12289
S&P/TSX 60	0.00192	0.96333	-9.80429	5.13746	-1.06437	11.05395

Table 4 Correlation Matrix between the Close-to-Close Returns and Open-to Open Indices Returns

Index	Close-to-close	Open-to open
CAC 40	0.21048	0.24595
DAX 30	0.18929	0.243
FTSE 100	0.20438	0.22753
Hang Seng	0.36883	0.40042
JSX Composite	0.29969	0.25774
KLSE	0.17504	0.109
KOSPI	0.32521	0.36155
KSE 100	0.04864	0.06683
NASDAQ	0.16246	0.04415
Nikkei 225	0.2991	0.24784
S&P 500	0.16545	-0.0461
SSE Composite	0.15223	0.06404
STI	0.09332	0.02181
S&P/TSX 60	0.38402	0.36488
TSEC	0.25789	0.32686

To investigate long term and short term relationship between return, further we performed Johansen Co-integration (1988) and Granger Causality test (1969). Volatility spillover between BSE and other indices are also investigated through bivariate BEKK model.

4. Long-run and short run interdependence of Indian market with other market.

In this section, we investigate the long run interdependence of BSE 30 index on other indices. Long-run integration is tested through Co-integration techniques whereas Granger Causality test and Vector autoregressive model are used for examining short run dynamics. Generally, it has been found that time series of indices are non-stationary and their returns are stationary. Johansen Co-integration requires same degree of integration; hence, we performed unit root rest on all indices, both in level and return series. After identifying the degree of cointegration, a bivariate co-integration technique is used to test the cointegration between BSE 30 with other indices. It might be possible that series are not cointegrated in long run but have short-run dependence. Whether there exists short run Granger causation between BSE 30 and other indices is tested through Granger Causality test. However, Granger Causality test does not explain whether there is a positive or negative relation between endogenous variables, and the strength of relationship, if any. This is investigated through Vector autoregressive model.

4.1 Unit root and stationarity test

Several tests have been developed to test the presence of unit root in a series. In this study, we focus on ADF test proposed by Dickey and Fuller (1979, 1981), and KPSS test proposed by Kwaitkowski et al (1992). In ADF test, the series has unit root, is the null hypothesis whereas in KPSS test, stationarity is the null hypothesis. Therefore KPSS test is used as confirmatory test of the results of ADF.

Unit root test is performed with all three specifications namely without drift in the mean equation, with drift but no trend and with trend and drift. Results of the model without the constant term are not reported here. However, it can be obtained on request from the authors. As expected, results of the ADF test (with drift but no trend, and with trend and drift) shows unit root in all indices and stationarity in all return series. Level series have unit root even corrected for drift and trend. All return series are stationary and possess no trend. This implies one degree of integration in the indices. KPSS results are in agreement with the ADF results except in the return series of BSE 30 index, Nikkei 225, JSX Composite, SSE Composite and STI indices. This may be due to poor size and power properties of these tests (Maddala and Kim, 1998). Hence, confirmatory tests are carried out for these three series using Phillips-Perron (PP, 1988) test and Elliott, Rothenberg and Stock (DF-GLS, 1996) test[2]. Both PP and DF-GLS tests support ADF tests and hence it can be concluded that the time series of all returns are stationary.

4.2 Johansen's cointegration techniques

The Johansen full information multivariate cointegrating procedure (Johansen, 1988; and Johansen and Juselius, 1990) is widely used to perform the cointegration analysis. It can only be performed between the series with same degree of integration. If the two or more series are

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[2] Results of unit root tests are not reported here and same can be obtained on request from the authors.

found to be co-integrating, then they are said to have common stochastic trend. They tend to move together in the long run but may divergence in short run. This test is based on vector auto regressive system of non stationary variable which is represented as

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-1} + v + \varepsilon_t \qquad [1]$$

Cointegration among vectors Y_t are examined using the properties of coefficient matrix Π. If the rank of the matrix Π is zero, no cointegration exists between the variables. If Π is the full rank (p variables) matrix then variables in vector Y_t are stationary process. If the rank lies between zero and p, cointegration exists between the variables under investigation. Two likelihood ratio tests are used to test the long run relationship (Johansen and Juselius, 1990).

(a) The null hypothesis of at most r cointegrating vectors against a general alternative hypothesis of more than r cointegrating vectors is tested by trace Statistics.

$$\text{Trace statistics is given by } (\lambda - trace) = -T \sum_{i=r+1}^{n} \ln(1 - \tilde{\lambda})_i \qquad [2]$$

where, T is the number of observations and λ is the eigenvalues.

(b) The null hypothesis of r cointegrating vector against the alternative of $r+1$ is tested by Maximum Eigen value statistic

$$\text{Maximum Eigen Value is given by } (\lambda - max) = -T \ln (1 - \tilde{\lambda}_{r+1}) \qquad [3]$$

If n-1 vector out of n vectors are found cointegrated (having a common stochastic trend), then all n vector are called "cointegrated in long run or represents long run equilibrium". As we are interested in investigating long-run interdependence between BSE 30 and other indices, bivariate cointegration test is performed. All 14 pairs of each closing and opening prices are investigated and results are presented in Table 5 (a) and 5 (b) respectively. All series have one degree of cointegration hence, two null hypotheses are tested: no co-integrating vector and at most one co-integration vector. Trace and Maximum Eigen Value statistics for all pairs are reported, which assumes the VECM with intercept in both error-correction and VAR representation[3]. However, other options in the equation like intercept, trend and quadratic trend give similar results in all cases. For opening prices, there is no cointegration of BSE 30 with any of the other indices. Only in the case of JSX Composite index the null hypotheses of no cointegration is rejected and hence shows cointegration of BSE 30 index with JSX Composite index for closing prices. All other indices show no co-integration with BSE 30 index. Further, we do not find any difference between Asian and other countries in terms of cointegration with BSE 30. This implies that there may be long run benefits from portfolio diversification across these markets. Similar to our result, Nath and Verma (2003) found no co-integration between NSE NIFTY[4], STI and TSEC indices.

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[3] Other options result can be obtained on request from the authors.
[4] NIFTY is the leading index of 50 large companies on the National Stock Exchange of India.

Table 5 (a): Johansen Bi-variate Co-integration Analysis for Closing Prices

index	No. of CE(s)= None			No. of CE(s)= Atmost 1			
	Eigenvalue	Trace Statistic	Max-Eigen Statistic	Eigenvalue	Trace Statistic	Max-Eigen Statistic	Conclusion
Nikkei 225	0.004078	7.880665	2.012175	1.40E-03	5.86849	2.012175	No co-integration
KOSPI	0.010085	14.5559	14.55491	6.89E-07	0.00099	0.00099	No co-integration
STI	0.006244	9.208669	0.213615	1.49E-04	8.995055	0.213615	No co-integration
TSEC	0.002918	5.6261	4.195854	9.95E-04	1.430246	1.430246	No co-integration
KLSE	0.006833	10.88512	9.845812	7.23E-04	1.03931	1.03931	No co-integration
SSE Composite	0.005684	8.357692	8.186083	1.19E-04	0.171608	0.171608	No co-integration
Hang Seng	0.004027	7.301906	5.794619	1.05E-03	1.507286	1.507286	No co-integration
JSX Composite	0.00758	16.16774*	10.92676	3.64E-03	5.240982*	5.240982*	Co-integration
KSE 100	0.006741	10.58822	9.713279	6.09E-04	0.874937	0.874937	No co-integration
FTSE 100	0.002951	6.023154	4.244341	1.24E-03	1.778813	4.244341	No co-integration
CAC 40	0.001693	4.165317	2.433096	1.21E-03	1.732222	1.732222	No co-integration
DAX 30	0.003348	5.62622	4.816012	5.64E-04	0.810208	0.810208	No co-integration
NASDAQ	0.005323	8.90204	1.238416	8.62E-04	8.90204	1.238416	No co-integration
S&P/TSX 60	0.005928	10.05191	1.513845	1.05E-03	8.53806	1.513845	No co-integration

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

Table 5 (b): Johansen Bi-variate Co-integration Analysis for Opening Prices

Index	No. of CE(s)= None			No. of CE(s)= Atmost 1			
	Eigenvalue	Trace Statistic	Max-Eigen Statistic	Eigenvalue	Trace Statistic	Max-Eigen Statistic	Conclusion
Nikkei 225	0.0045	8.2008	6.1369	0.0015	2.064	2.064	No co-integration
KOSPI	0.01	13.7752	13.7744	0	0.0008	0.0008	No co-integration
STI	0.0066	9.2417	9.0971	0.0001	0.1446	0.1446	No co-integration
TSEC	0.0075	11.8292	10.205	0.0012	1.6243	1.6243	No co-integration
KLSE	0.0067	10.035	9.1376	0.0007	0.8974	0.8974	No co-integration
SSE Composite	0.007	9.6306	9.5605	0.0001	0.0701	0.0701	No co-integration
Hang Seng	0.0046	7.8596	6.2655	0.0012	1.5941	1.5941	No co-integration
JSX Composite	0.0065	14.9499	8.8687	0.0044	6.0812	6.0812	No co-integration
KSE 100	0.0072	10.4915	9.9141	0.0004	0.5775	0.5775	No co-integration
FTSE 100	0.003	5.8351	4.047	0.0013	1.7881	1.7881	No co-integration
CAC 40	0.0018	4.1797	2.5158	0.0012	1.6639	1.6639	No co-integration
DAX 30	0.0033	5.2588	4.5219	0.0005	0.7369	0.7369	No co-integration
NASDAQ	0.0059	9.3442	8.1167	0.0009	1.2275	1.2275	No co-integration
S&P/TSX 60	0.0032	5.7435	4.3092	0.0011	1.4343	1.4343	No co-integration

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

4.3 Granger causality analysis

Cointegration indicates long run relationship between the stochastic variable, however, it might be possible that two time series are not cointegrated in long run but, there may exist short run causal inter-relationship. Short run interrelationship is examined through Granger Causality test. Granger explains whether the explanatory power of the bivariate model can be improved using lag variable. If the improvement is found then one variable is to be Granger cause the second endogenous variable. This causality test assume VAR or VECM model depending upon the degree of cointegration and Wald test is performed on the unrestricted and restricted version of the model. We performed two-way Granger causality test on BSE 30 and other indices i.e.

whether BSE 30 Granger causes index return or vice versa for both close-to-close return and open-to-open return. As Granger causality test is sensitive to lag selection of endogenous variable, optimal lag length is selected based on minimum AIC criteria. The results of the test are presented in Table 6.

As discussed in section 3, indices namely CAC 40, DAX 30, FTSE 100, KSE 100, NASDAQ and S&PTSX indices open after BSE 30 index and also close after it. Hence, some information flow may be expected to flow from BSE 30 index to these indices. Similarly, Nikkei 225, KOSPI, STI, TSEX, SSE Composite, Hang Seng, and JSX Composite open before BSE 30 index and hence may affect BSE 30. NASDAQ, and S&P/TSX 60 do not have overlapping time; however the leading indices of USA namely NASDAQ may influence BSE 30 returns.

Table 6 Pair-wise Granger Causality Tests for Close-to-Close Return and Open-to-Open Return

	Close-to-close return		Open-to-open return	
Index	**BSE 30 Granger Causes Index return**	**Index Granger Causes BSE 30 return**	**BSE 30 Granger Causes Index return**	**Index Granger Causes BSE 30 return**
Nikkei 225	Yes	No	Yes	Yes
KOSPI	Yes	No	Yes	Yes
STI	No	Yes	No	No
TSEC	Yes	No	No	Yes
KLSE	No	No	No	Yes
SSE Composite	No	No	No	No
Hang Seng	No	Yes	No	Yes
JSX Composite	No	No	No	No
KSE 100	Yes	No	Yes	No
FTSE 100	No	Yes	No	Yes*
CAC 40	No	Yes	No	Yes
DAX 30	No	Yes	Yes	No
NASDAQ	No	No	Yes	Yes
S&P/TSX 60	Yes	Yes	Yes	Yes

It has been found that open-to-open and close-to-close returns of KOSPI and Nikkei are Granger caused by BSE 30 and former indices only influence the opening return of BSE 30. Hang Seng indices influence both open-to-open and close-to-close return of BSE 30 but not the other way around. Taiwan index TSEC open-to-open return Granger causes BSE 30 return however close-to-close return of latter causes former return. BSE 30 also influences both open-to-open and close to close return of Pakistan Index (KSE 100) but is not influenced by the latter index. European indices namely CAC 40, FTSE 1000, and DAX 30 Granger cause close-to-close return of BSE 30 and the latter only affects open-to-open return of the former indices. Two-way Granger causality is found between of BSE 30 and NASDAQ open-to-open return. Both ways causality is found with S&P/TSX 60 for both returns. Other markets do not influence each other.

4.4 Estimation of return spillover using Vector autoregressive (VAR) model

Granger causality test explains only the inter-dependence of endogenous variables. It does not provide the strength of interrelationship nor indicate whether the dependency is negative or positive. VAR model is generally used to estimate the strength and sign of cross-correlation between returns. We performed bivariate VAR model between BSE 30 and other indices. The

lag length of endogenous variable is selected based on minimum AIC criterion. Results of the VAR model estimates on close-to-close and open-to-open returns are presented in Table 7 (a) and 7 (b).

It has been found that most of the Asian, European North American markets, considered in our analysis affect the conditional mean of close-to-close return of India except Indonesia, Malaysia, Pakistan, Japan, China and Taiwan. However, Indian market affects Germany, Indonesia, Korea, Pakistan, US, Japan and Taiwan markets. All markets except Germany, Indonesia, Pakistan, China and Singapore affect the open-to-open conditional mean return of Indian market. At the same time significant return spillover is found from India to Germany, Malaysia, Korea, Pakistan, US, Japan and Singapore. The mean spillover to India and from India to other countries is only positive. Hence, there exists significant bilateral conditional return spillover between Indian and Japan, Korea, Sigapore, US and Germany. One way Return spillover i.e. from Indian market to Indonesia, Malaysia, Pakistan and Taiwan is found. On the other hand France and Hong Kong market affect Indian market but do not get influenced by the Indian market.

Both Granger Causality test and VAR model estimate the lag effect of returns on the endogenous variable. Also, bivariate VAR model explains the cross-correlation only among two endogenous variables under consideration. It is likely that same information would affect all the indices in the similar way and the correlation estimated through bivariate VAR model would be significant for all the indices and these may be misleading. For example, Japan and Korea index open before other Asian markets and these markets may affect other markets like Singapore, Taiwan, or Hong Kong. Running a bivariate model with Singapore or Taiwan or Hong Kong with BSE 30 may show significant cross-correlation but possibly the effect is coming from Japan or Korea. Bivariate VAR model does not provide partial correlation. This might be the reason behind the non-conclusive results we found in Granger Causality test and VAR model results. Another problem with the Granger Causality test and VAR model is that it considers only the effect of past value but it is important to consider the same day effect of one index on another while analyzing the return and volatility spillover.

To correct the problem associated with bivariate model, we performed VAR model considering all indices as endogenous variable. The partial cross-correlation is estimated through VAR (15) model and results are presented in Table 8 (a) and 8 (b). Table 8 (a) explains the partial cross-correlation of close-to-close returns and table 8 (b) the partial cross-correlation of open-to-open return. As expected, we found that one day lag of the NASDAQ, S&P/TSX 60, DAX, and FTSE returns are affecting the current period returns of most of the Asian and other countries. European (FTSE, CAC and DAX), US and Canada markets which open/close after the other Asian market, therefore any information (new/old) would be incorporated in these markets and would affect the next day open/close return of the indices. However, one day lag open-to-open returns of some Asian indices such as Nikkei, Kospi, STI, KLSE and Taiwan and Hang-Seng also influence each other and other indices. It is important to note that European indices are mostly correlated with each other and affected by NASDAQ lag return. Indian Index BSE 30 affects next day close-to-close returns of Nikkei, TSEC and DAX. In this analysis the same day effect of return of indices is ignored.

Table 7 (a) Bivariate VAR Model (BSE 30 and Other Indices) Estimates of Close-to-Close Return

Dependent variables	Parameters	Nikkei	Kospi	STI	TSEC	Klse	SSE	Hang Seng	JKSE	KSE	FTSE	CAC 40	DAX	NASDAQ	S&P TSX
BSE 30	CONST1	0.00055	0.00055	0.0005	0.0005	0.0005	0.00057	0.00054	0.0006*	0.0005	0.0007**	0.0007**	0.0007**	0.00062	0.00063
	Index (t-1)	0.04049	0.055**	0.093**	-0.02511	0.0053	0.00919	0.0394	-0.024	-0.0018	0.12521**	0.0935**	0.11935**	0.03227	0.03358
	Index (t-2)	-0.0107	0.00684	0.0512			0.01714	0.087**	-0.019*	0.0056	0.0725**	0.0627**	0.02906	0.00427	0.02304
	Index (t-3)		0.01482				0.01667				0.07372**	0.0588**	0.03809	0.03781*	0.03804
	Index (t-4)						-0.00681				-0.01603	0.00251	0.00825	0.0102	0.1198**
	Index (t-5)						-0.0211				0.09622**	0.0925**	0.0654**	0.00085	0.092**
	BSE (t-1)	-0.00054	-0.0124	-0.0182	0.01564	0.00874	0.01141	-0.0046	0.0156	0.01	-0.01085	-0.0111	-0.01405	0.00532	0.00174
	BSE (t-2)	-0.05301*	-0.060*	-0.07**			-0.055**	-0.082*	-0.049	-0.05**	-0.0683**	-0.071**	-0.0685**	-0.4664	-0.063**
	BSE (t-3)		-0.0337				-0.0347				-0.04477*	-0.0483**	-0.04422	-0.04223	-0.04319
	BSE (t-4)						0.04631*				0.04227	0.03934	0.03412	0.04049	0.02557
	BSE (t-5)						-0.0632**				-0.0781**	-0.0811**	-0.076**	-0.0658**	-0.088**
Index	CONST2	-0.00004	0.00052	0.0002	0.00024	0.0003*	0.00039	0.00022	0.0011	0.0007	-0.00023	-0.00021	-0.00041	-0.00046	-0.00013
	Index (t-1)	-0.05225	-0.0371	-0.0043	0.00527	0.15321	0.0013	0.049*	0.063**	0.024	-0.05648**	-0.0545**	-0.0517**	0.00894	-0.08292
	Index (t-2)	-0.03062*	-0.067**	-0.0361			-0.02243	-0.00168	-0.02375	0.05**	-0.00582	-0.02575	-0.00823	-0.07537**	-0.04242
	Index (t-3)		-0.057**				0.02292				0.00462	-0.02947	-0.0129	-0.02828	-0.01069
	Index (t-4)						-0.01744				-0.05185*	-0.03339	0.00749	0.01548	0.04737
	Index (t-5)						0.00198				-0.0192	-0.04121	-0.0617**	-0.04157	0.00186
	BSE (t-1)	0.05425**	0.071**	0.02	0.0914**	-0.001*	-0.01673	-0.0019	0.00538	0.05**	-0.01835	-0.01278	0.03075	0.05595	0.10873
	BSE (t-2)	-0.03844	-0.028	0.012			0.01275	-0.0228	0.04884**	0.0289	-0.00485	0.01033	0.00383	0.01663*	0.00245
	BSE (t-3)		0.02454				-0.03486				0.00178	-0.00775	-0.00033	0.01546	0.00833
	BSE (t-4)						-0.00642				-0.00817	-0.00711	-0.00797	-0.01513	0.00007
	BSE (t-5)						0.02925				-0.01314	0.00311	0.00033	-0.00129	-0.01872

*(**) denotes rejection significance at the 10(5%) level

Table 7 (b) Bivariate VAR model (BSE 30 and Other Indices) estimates of Open-to-Open Return

Dependent variables	Parameters	Nikkei	Kospi	STI	TSEC	Klse	SSE	Hang Seng	JKSE	KSE	FTSE	CAC 40	DAX	NASDAQ	S&P TSX
BSE 30	CONST1	0.0005	0.0004	0.00044	0.0004	0.0004	0.00041	0.00045	0.0004	0.00039	0.00048	0.0004	0.0004	0.00046	0.00045
	Index (t-1)	0.0446	-0.0092	0.01352	-0.0059	-0.0835	0.03541	-0.01467	-0.0355	-0.01128	-0.01726	0.063*	0.0174	0.00946	0.02327
	Index (t-2)	0.0917**	0.069**	0.07691*	0.0286	0.1316**		0.0776**	0.065*	0.04987*	0.0861**	-0.001	0.03	0.04464*	0.14142**
	Index (t-3)	0.0743**	0.067**	0.05188	0.087**	0.0305		0.1183**		0.00728	0.06655	0.08**	0.06*	0.05281**	0.08712**
	Index (t-4)		0.0369	-0.01177						0.02812		0.035		0.05894**	0.05358
	Index (t-5)		0.071**							0.00643					
	BSE (t-1)	-0.104**	-0.085**	-0.0893**	-0.090**	-0.084**	-0.0857**	-0.088**	-0.08**	-0.0823**	-0.0883**	-0.098**	-0.095**	-0.09186**	-0.0937**
	BSE (t-2)	-0.071**	-0.078**	-0.065**	-0.053**	-0.0514*		-0.070**	-0.06**	-0.05044	-0.0594**	-0.047*	-0.056**	-0.05315*	-0.0595**
	BSE (t-3)	-0.075**	-0.084**	-0.0649**	-0.081**	-0.057**		-0.090**		-0.05243*	-0.065**	-0.068**	-0.068**	-0.06137**	-0.0719**
	BSE (t-4)		0.0315	0.05089*						0.04344*		0.047*		0.0365	0.03165
	BSE (t-5)		-0.060**							-0.03214					
Index	CONST2	-0.00034	0.00026	-0.00006	0	0.0002	0.00048	0.00005	0.0006	0.00059	-0.00033	-0.00006	0	-0.00024	0
	Index (t-1)	-0.06**	-0.091**	-0.1031**	-0.067**	0.0788**	-0.04422	-0.06**	0.041	0.00867	-0.1164**	-0.088**	-0.087**	-0.09723**	-0.0609**
	Index (t-2)	-0.01415	-0.054**	-0.01437	0.055*	0.0808**		-0.00348	0.011	-0.00948	-0.03028	-0.058	-0.03162	0.00697	0.00566
	Index (t-3)	0.00087	-0.0258	-0.02446	-0.0145	-0.066**		0.017		0.03768	-0.05272*	-0.047**	-0.064	-0.01341	0.0093
	Index (t-4)		-0.0461	0.03328						0.02086		-0.0405*		-0.02687	0.06058**
	Index (t-5)		0.095**							-0.07788*					
	BSE (t-1)	0.079**	0.08**	0.0432**	0.024	0.029**	-0.00361	0.00614	0.001	0.04772*	0.03471*	-0.0036	0.071**	0.21561**	0.11773**
	BSE (t-2)	0.01437	0.0006	0.02589	-0.005	0.0077		0.01831	0.033	0.069**	0.00263	0.0297	0.03503	0.03793	0.04958**
	BSE (t-3)	0.0054	0.00504	-0.01681	-0.038	0.0025		-0.0362		0.00219	-0.0235	-0.034	-0.0066	-0.00325	-0.03237*
	BSE (t-4)		0.03509	-0.00274						0.01488		-0.006		0.00939	-0.034*
	BSE (t-5)		-0.085**							0.03732					

*(**) denotes rejection significance at the 10(5%) level

Table 8 (a) Parameter Estimates of VAR (15) Model of Close-to-Close-Return

Variable	Nikkei 225	KOSPI	STI	TSEC	KLSE	SSE	Hang Seng	JSX	BSE 30	KSE 100	FTSE 100	CAC 40	DAX 30	NASDAQ	S&P/TSX 60
Nikkei 225	-0.07**	-0.032	0.060	-0.038	-0.11**	-0.003	-0.025	-0.016	0.041*	0.033	-0.074	0.078	0.128**	0.204**	0.024
KOSPI	-0.045	-0.086**	0.098	-0.020	-0.104	0.016	-0.002	-0.017	0.048	0.012	-0.028	-0.050	0.158**	0.210**	0.106**
STI	-0.032	-0.025	0.016	-0.019	-0.036	0.018	-0.026	-0.029	0.031	0.023	0.036	-0.059	0.080**	0.125**	0.042
TSEC	-0.005	-0.002	0.122**	-0.037	0.090*	0.023	-0.021	-0.08**	0.067**	-0.010	-0.18**	0.069	0.092**	0.146**	0.084*
KLSE	-0.030	-0.043**	0.016	0.018	0.14**	0.013	-0.013	0.011	-0.010	0.025	0.019	0.020	0.030	0.074**	0.076**
SSE	-0.035	0.002	-0.030	0.010	-0.051	-0.003	0.053	0.047	-0.032	-0.006	0.045	-0.022	0.007	0.015	0.062
Hang Seng	-0.08**	-0.008	0.060	-0.032	-0.096	-0.005	0.021	-0.025	0.001	0.007	0.21**	-0.11**	0.046	0.185**	0.081**
JSX	-0.047	0.018	-0.012	0.001	-0.008	0.035	-0.044	0.070**	0.004	-0.001	-0.097	0.041	0.094**	0.055**	0.067
BSE 30	0.009	0.042	0.076	-0.066	-0.023	0.011	-0.022	-0.042	-0.010	-0.005	0.074	-0.14**	0.090**	0.080**	0.095**
KSE 100	-0.057	0.040	0.041	0.031	-0.054	0.009	-0.002	-0.005	0.029	0.027	-0.034	0.004	0.037	-0.019	0.072
FTSE 100	-0.007	-0.033	-0.019	0.002	-0.028	0.012	0.026	-0.021	0.002	-0.001	-0.029	-0.17**	0.094**	0.146**	-0.022
CAC 40	0.002	-0.033	-0.020	-0.021	-0.020	0.024	0.014	-0.033	0.015	0.010	0.041	-0.29**	0.148**	0.201**	-0.050
DAX 30	-0.043	-0.044	-0.035	0.018	0.039	0.020	0.070	-0.046	0.057**	0.027	0.148**	-0.19**	-0.066	0.171**	-0.041
NASDAQ	-0.017	0.002	-0.008	-0.12**	0.112	0.020	0.054	-0.036	0.021	0.022	0.222**	-0.151	-0.002	0.080**	-0.144**
S&P/TSX 60	-0.026	-0.024	0.035	-0.039	0.018	-0.006	0.048	-0.020	0.008	0.003	0.170**	-0.13**	-0.010	0.097**	-0.153**

*(**) denotes rejection significance at the 10(5%) level

Table 8 (b) Parameter Estimates of VAR (15) Model of Open-to-Open-Return

Variable	Nikkei 225	KOSPI	STI	TSEC	KLSE	SSE	Hang Seng	JSX	BSE 30	KSE 100	FTSE 100	CAC 40	DAX 30	NASDAQ	S&P/TSX 60
Nikkei 225	-0.058*	0.001	-0.021	-0.002	-0.068	-0.006	0.008	0.011	0.046	0.024	-0.072	0.22**	-0.10**	0.056**	0.098**
KOSPI	-0.10**	-0.058	-0.054	0.066	-0.17**	0.027	-0.037	-0.005	0.077**	0.019	0.051	0.082	-0.050	0.072**	-0.087
STI	-0.038	-0.008	-0.057**	0.015	-0.051	0.012	-0.060*	-0.025	0.043	0.018	-0.010	0.056	-0.040	0.026	0.073*
TSEC	0.028	-0.052	-0.031	-0.052	0.072	0.025	0.016	-0.021	0.039	-0.003	-0.044	0.053	-0.075	0.008	0.062
KLSE	-0.002	-0.023	-0.013	0.002	0.069**	-0.011	0.004	0.035*	0.002	0.006	-0.018	0.016	0.058**	0.025	0.064**
SSE e	-0.003	-0.027	0.040	0.066*	-0.013	-0.049*	-0.037	0.051	-0.035	-0.025	-0.012	0.058	-0.004	-0.026	0.088
Hang Seng	-0.07**	0.004	-0.023	0.012	-0.078*	-0.004	-0.069*	-0.013	0.000	-0.003	0.052	0.047	-0.058	0.118**	0.015
JSX	-0.035	0.051*	-0.061	-0.012	0.006	0.013	-0.084	0.070	0.004	-0.013	-0.103	0.143**	0.024	-0.002	0.028
BSE 30	0.099**	-0.08**	0.031	-0.010	-0.074	0.040	-0.049	-0.018	-0.07**	-0.013	-0.079	0.088	-0.019	0.010	0.109**
KSE 100	-0.005	-0.027	0.093*	0.007	0.016	0.036	-0.038	-0.037	0.043	0.011	-0.066	0.016	0.035	-0.051	0.109**
FTSE 100	-0.010	-0.008	-0.062*	0.019	-0.13**	0.004	0.055*	0.040*	-0.012	0.006	-0.180	0.146**	-0.066*	0.127**	0.093**
CAC 40	-0.042	-0.050	-0.045	0.021	-0.105	0.009	0.040	-0.012	0.004	0.006	0.090*	-0.16**	0.022	0.073**	0.012
DAX 30	0.001	-0.038	-0.056	0.033	-0.085	0.014	0.056	0.023	0.037	0.010	0.071	0.118**	-0.27**	0.155**	0.035
NASDAQ	-0.057	-0.051	-0.006	0.106**	-0.121*	0.014	0.065	-0.020	0.012	0.026	0.011	-0.042	0.045	-0.057	-0.101
S&P/TSX 60	-0.06**	-0.025	-0.019**	0.076**	-0.005	0.007	0.020	-0.023	0.044	-0.003	0.050	0.061	-0.07**	0.008	-0.077**

*(**) denotes rejection significance at the 10(5%) level

To get a closer picture of information flow and importance of markets in information dissipation, we performed VAR/univariate model for index returns and incorporated the same day effect[5] of index return which open/close before the index under consideration. If indices open/close at the same time we consider them as endogenous variable and estimate the parameters using VAR model, otherwise univariate model of index return is analyzed. Indices which open/close before the index under examination, the same day returns of these indices are used as explanatory variable and those indices which open/close after, the one day lag returns are used as explanatory variable. For example, while modeling BSE 30 returns, the same day returns of Nikkei, Kospi, STI, TSEC, KLSE, SSE, Hang Seng and JSX (these indices open/close before BSE 30) and one day lag return of KSE, FTSE, CAC, DAX, NASDAQ, S&P/TSX 60 (these indices open/close after BSE 30) are considered as explanatory variable. In univariate case, five lag lengths and one lag length in VAR model of the dependent variable is considered. We estimated the parameters for all 15 indices and for both open-to-open and close-to-close returns. Results of close-to-close and open-to-open returns of all indices are given in Table 9 (a) and 9 (b) respectively.

Results of the VAR and univariate models support the fact that the open-to-open or close-to-close returns of indices are mostly affected by indices which open/close just before them. However, it also indicated the strength of some market in transmitting the information through return. Nikkei and Kospi market open first (According to GMT) and a VAR model using Nikkei and Kospi returns as endogenous variable and lag of other indices' return as explanatory variable is performed. It is found that the past returns (last day) of NASDAQ, S&PTCX DAX and CAC influence their return. Just after them STI, TSEC and KLSE markets open and their returns are mostly affected by same day Nikkei and Kospi returns. However, coefficient of one day past returns of NASDAQ is also significant for these markets. SSE return is affected by KLSE return only, where as Hang-Seng return is influenced by Asian (Nikkei, Kospi, and STI) as well as FTSE and NASDAQ returns. Indian and Pakistan market open after other Asian markets. Pakistan index is only affected by KLSE, however, there is strong correlation between BSE 30 and Kospi, STI Hang-Seng and JKSE. Results of the Asian market indicate that the information flows from Japan, Korea to Singapore, Taiwan, Malaysia to Hong-Kong to India. Hong-kong market is also influenced by European markets. While analyzing the European market, we found that the FTSE return (which opens before DAX and CAC) is affected by same day returns of Asian markets such as Nikkei, STI and Hang-seng indices, and one day past returns of NASDAQ. It is important to note that many Asian markets open after Nikkei, STI and Hang-Seng, but they do not affect FTSE returns. DAX and CAC are mostly influenced by FTSE market. In Asian countries, DAX returns are only affected by Nikkei. NASDAQ returns are influenced mostly by same day DAX returns; however, Indian and Korean markets also affect the NASDAQ return. Canada market which opens/closes in the last (according to GMT) is mostly affected by NASDAQ market. Significant cross correlation has been found with London, India and Japan market. Similar pattern is found for both close-to-close and open-to-open return.

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[5] This model has some simultaneity bias because of common trading period (only possibility is to consider overnight returns (close-to-open returns) for the analysis, but in this also we are ignoring the information dissipation through trading). However, to get a closer picture of information flow, it is important to introduce the same day returns of different indices into the model. The idea here is to understand the information flow among different market rather than knowing the exact partial correlation among these markets.

Table 9(a) VAR/Univariate Model for Close-to-Close Return

Parameters	NIKKEI	KOSPI	STI	TSEC	KLSE	SSE	JKSE	Hang_Seng	sensex	KSE	FTSE	CAC	DAX	Nasdaq	S&PTSX
CONST	0	0.001	0	0	0	0	0.001	0	0	CONST	0.001	0	0	0	0
AR1	-0.07**	-0.08**	-0.02	-0.013	0.153**	-0.01	0.081**	0.015	-0.007	0.018	-0.066	-0.07**	-0.17**	-0.031	-0.08**
AR2						-0.028	-0.002	-0.032*	-0.05**	0.046*	-0.023			-0.06**	-0.013
AR3						0.025	0.005	-0.007	-0.043**	0.01	-0.029			-0.037	-0.009
AR4						-0.009	-0.011	-0.028	0.048**	0.046*	-0.05**			0.007	0.034**
AR5						0.02	-0.004	0.009	-0.061**	-0.012	-0.05			-0.018	0.003
NIKKEI(t-1)		-0.031													
KOSPI(t-1)	-0.045														
STI(t-1)	0.062	0.099**		-0.007	0.012										
TSEC(t-1)	-0.04	-0.02	0.096**	0.008	0.147**										
KLSE(t-1)	-0.11**	-0.10**	-0.009												
SSE(t-1)	-0.004	0.016	0.015	0.016	0.012										
Hang_Seng(t-1)	-0.016	-0.018	-0.022	-0.07**	0.011	0.027	-0.036								
JKSE(t-1)	-0.022	-0.002	-0.02	0.007	-0.026	0.038	-0.011								
sensex(t-1)	0.040**	0.048	0.011	0.046*	-0.021	-0.039		-0.030**							
KSE(t-1)	0.033	0.012	0.013	-0.02	0.021	-0.018	-0.014	-0.014	-0.002						
FTSE(t-1)	-0.074	-0.028	0.06	-0.15**	0.028	0.036	-0.102*	0.224**	0.068	-0.002					
CAC(t-1)	0.08	-0.049	-0.067	0.071	0.017	-0.033	0.039	-0.115**	-0.103	-0.003	-0.15**		0.047**		
DAX(t-1)	0.126**	0.158**	0.015	0.019	0.002	-0.004	0.053	-0.031	0.033	0.03	0.060*	0.120**			
Nasdaq(t-1)	0.205**	0.210**	0.032*	0.042*	0.040**	-0.017	-0.023	0.057**	-0.016	-0.034	0.078**	0.036**	0.003**		
S&PTSX(t-1)	0.024	0.106**	0.013	0.049	0.063**	0.032	0.024	0.025	0.051	0.057	-0.042	-0.026	-0.012	-0.079	
NIKKEI(t)			0.239**	0.199**	0.088**	0.031	0.027	0.163**	0.042	0.027	0.054**	0.004	-0.023	-0.039	0.060**
KOSPI(t)			0.214**	0.302**	0.081**	-0.005	0.046*	0.150**	0.058**	-0.002	0.029	0.017	0.078**	0.059*	-0.003
STI(t)						0.084	0.279**	0.370**	0.244**	0.068	0.224**	0.002	-0.008	0.004	0.008
TSEC(t)						0.029	0.099**	0.070**	0.046	0.005	-0.024	0.008	0.012	0.074**	-0.01
KLSE(t)						0.224**	0.220**	0.109**	-0.065	0.107**	-0.024	0.026	-0.012	0.052	0.045
SSE(t)							0.026	0.067**	0.023	0.01	-0.025	-0.019	-0.012	-0.013	0.012
JKSE(t)							0.013	0.174**	-0.059	0.125**	0.011	0.016	0.052	-0.024	
Hang_Seng(t)								0.188**	0.038	0.016	-0.009	-0.009	-0.061	-0.002	
sensex(t)									0.014	0.029	0.019	0.031	-0.07**	0.043**	
KSE(t)										0.025	0.007	0.006	-0.025	0.014	
FTSE(t)											1.029**	0.991**	-0.067	0.159**	
CAC(t)												0.007	0.005		
DAX(t)												0.620**	0.039		
Nasdaq(t)													0.344**		

*(**) denotes rejection significance at the 10(5%) level.

Table 9 (b) VAR/Univariate Model for Open-to-Open Return

Parameters	NIKKEI	KOSPI	STI	TSEC	KLSE	SSE	JKSE	Hang_Seng	sensex	KSE	FTSE	CAC	DAX	Nasdaq	S&PTSX
CONST	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
AR1	-0.059*	-0.057	-0.030	-0.08**	0.090**	-0.046	0.063**	-0.040	-0.1**	0.017	-0.17**	-0.23**	-0.07**	0.002	-0.012
AR2						0.044	0.011	0.001	-0.06**	-0.010	-0.06**			0.000	-0.016
AR3						0.029	0.006	-0.019	-0.035	0.044	-0.06**			0.002	-0.007
AR4						-0.020	0.004	-0.003	0.047*	0.021	-0.024			0.002	0.043**
AR5						-0.041	-0.011	-0.040**	-0.005	-0.07**	-0.008			-0.015	0.003
NIKKEI(t-1)		-0.10**													
KOSPI(t-1)	0.000														
STI(t-1)	-0.019	-0.059		-0.001	0.017										
TSEC(t-1)	-0.004	0.069**	0.013		0.170**										
KLSE(t-1)	-0.067	-0.17**	-0.008	-0.008											
SSE(t-1)	-0.006	0.029	0.005	0.014	-0.012										
Hang_Seng(t-1)	0.010	-0.004	-0.026	-0.020	0.032*	0.050									
JKSE(t-1)	0.010	-0.040	-0.047*	0.039	0.005	-0.007	0.163**								
sensex(t-1)	0.046	0.077**	0.010	-0.004	-0.010	-0.030	-0.018	-0.032							
KSE(t-1)	0.023	0.019	0.006	-0.017	0.002	-0.031	-0.017	-0.016	-0.011						
FTSE(t-1)	-0.070	0.048	-0.008	-0.035	-0.007	-0.017	-0.12**	0.045	-0.032	-0.040					
CAC(t-1)	0.219**	0.078	-0.024	-0.027	-0.013	0.054	0.097**	-0.010	0.028	0.030	0.094**		0.009		
DAX(t-1)	-0.01**	-0.046	0.001	-0.034	0.068	0.005	0.040	-0.024	0.015	0.014	-0.014	0.164**			
Nasdaq(t-1)	0.055**	0.073**	-0.008	-0.034	0.011	-0.033	-0.035	0.091**	-0.038	-0.045	0.092**	-0.05**	0.024		
S&PTSX(t-1)	0.098**	-0.088	0.076**	0.090**	0.059**	0.056	-0.004	-0.022	0.119**	0.093*	0.073**	-0.024	-0.013	-0.037	
NIKKEI(t)			0.243**	0.135**	0.111**	0.069	0.039	0.086**	-0.014	-0.062	0.145**	-0.10**	-0.021	0.004	0.004
KOSPI(t)			0.301**	0.469**	0.075**	-0.040	0.027	0.161**	0.130**	-0.028	-0.011	0.140**	0.127**	0.190**	0.026
STI(t)						0.089	0.228**	0.431**	0.125**	0.069	0.130**	0.119**	0.080**	0.050	0.000
TSEC(t)						-0.004	0.022	0.087**	0.101**	0.015	-0.020	0.146**	0.126**	0.057**	-0.033*
KLSE(t)						0.234**	0.187**	0.061*	-0.13**	0.124**	-0.08**	-0.13**	-0.11**	0.068	0.004
SSE(t)							0.032	0.069	-0.030	0.027	-0.03**	-0.020	-0.022	0.009	0.030**
JKSE(t)								-0.006	0.265**	-0.035	0.205**	0.160**	0.088**	0.047	0.007
Hang_Seng(t)									0.130**	0.061*	0.066**	-0.05**	-0.010	-0.11**	0.007
sensex(t)										0.049*	0.015	-0.017	-0.029*	0.016	0.009
KSE(t)											0.035**	0.025	0.027	-0.002	-0.018
FTSE(t)												0.577**	0.764**	-0.28**	0.051
CAC(t)														0.902**	0.099**
DAX(t)														-0.24**	0.031
Nasdaq(t)															0.330**

*(**) denotes rejection significance at the 10(5%) level

It can be concluded from the analysis that the information flows from one market to another market as they open/close. However, in Asia, Japan, Singapore and Hong Kong market are more influential than other market. It also supports the fact that the correlation between European markets has increased after the introduction of EURO (1st Jan 1999). Among the European markets, London and German markets seem to be and the important markets. US influences both Asian and European markets and US market comes out to be the most integrated market (integrated with influential Asian and European Market).

5. Volatility spillover between BSE 30 and other indices

One of our primary interests in this paper is to investigate the information spillover to-and-fro Indian markets in relation to other Asian, European and North American markets. Therefore, here, we investigated the information spillover to-and-fro reference market (represented by BSE 30) through measuring volatility spillover. Information flow across markets through return (correlation among first moment) might not be significant and visible; however, they may have strong effect through volatility (correlation among second moment). As, volatility is measurement of risk, understanding of volatility spillover across markets helps in estimation of diversified portfolio, executing hedging strategy and asset allocation.

After the seminal work of Engle, Ito and Lin (1990), who applied multivariate GARCH model in estimating volatility spillover between US and Japanese foreign exchange markets, multivariate GARCH model has been widely applied to equity, exchange, bond market etc. In this paper we also applied multivariate GARCH model, BEKK (developed by Baba, Engle, Kraft and Krone), to investigate volatility spillover between BSE 30 and other indices. It is interesting to see whether geographical proximity leads to more spillover or other factors like maturity of the market, bilateral trade or economy, openness, etc. The VAR (k)-BEKK (1,1) model to estimate volatility spillover is explained below

BEKK: VAR(k)-GARCH(1,1)

Let endogenous variable Y_t is N×1 vector

$$Y_t = C + B_1 Y_{t-1} + \ldots\ldots\ldots + B_k Y_{t-k} + E_t \tag{4}$$

is a mean equation. The error term has multinomial normal distribution as

$$E_t | \psi_{t-1} \sim N(0, H_t)$$

The BEKK(p,q) representation of the variance of error term H_t

$$H_t = C_0' C_0 + \sum_{i=1}^{q} A' \varepsilon_{t-i} \varepsilon_{t-i}' A_i + \sum_{i=1}^{p} G_i' H_{t-i} G_i \tag{5}$$

Where, Ai and Gi are k×k parameter matrix and C0is k×k upper trangular matrix. Bivariate VAR(k) BEKK (1,1) model can be written as

$$H_t = C_0'C + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{2,t-1}\varepsilon_{1,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \times \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}' H_{T-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \qquad [6]$$

Or in more simpler way,

$$h_{11} = c_1 + a^2{}_{11}\varepsilon^2{}_{1,t-1} + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a^2{}_{21}\varepsilon^2{}_{2,t-1} + g^2{}_{11}h^2{}_{11,t-1} + 2g_{11}g_{21}h_{12,t-1} + g^2{}_{21}h^2{}_{22,t-1}$$

$$h_{12} = c_2 + a_{11}a_{12}\varepsilon^2{}_{1,t-1} + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon^2{}_{2,t-1} + g_{11}g_{12}h_{11,t-1} + (g_{21}g_{12}$$
$$+ g_{11}g_{22})h_{12,t-1} + g_{21}g_{22}h_{22,t-1}$$

$$h_{22} = c_3 + a^2{}_{12}\varepsilon^2{}_{1,t-1} + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a^2{}_{22}\varepsilon^2{}_{2,t-1} + g^2{}_{12}h^2{}_{11,t-1} + 2g_{12}g_{22}h_{12,t-1} + g^2{}_{22}h^2{}_{22,t-1}$$
$$[7]$$

In the BEKK representation of volatility, the parameter, a_{21} is the volatility spillover from market 2 to market 1, and a_{12} indicates the spillover from market 1 to market 2. Hence, the statistical significance of these parameters tells about the volatility spillover.

As we discussed in the return spillover section, BEKK model also considers only the lag effect and including all indices together will create the optimization problem. As we can see the bivariate BEKK (1,1) requires 11 parameters and BEKK (1,1) with 15 variables requires 570 parameters and optimization will be tedious. We approach the problem in two ways. The volatility spillover between domestic index "BSE30" and other 14 indices are estimated through BEKK (1,1) model and we employ two-stage GARCH approach to examine the volatility spillover across all indices. In this method we also considered the same day effect and estimated the partial coefficient of the parameters. In the first stage, we fitted the AR(1)-GARCH(1,1) model to each indices and obtained the residuals from the mean equation.

$$r_{jt} = a + b_{j1}r_{jt-1} + \varepsilon_{jt}$$
$$\text{where, } \varepsilon_{jt} \mid \psi_{jt-1} \sim N(0, \sigma_{jt}^2) \text{ and}$$
$$\sigma_{jt}^2 = \alpha_0 + \alpha_{j1}\varepsilon_{t-1}^2 + \beta_{j1}\sigma_{jt-1}^2 \qquad [8]$$

r_{jt} is the return of the jth index at time t and ε_j is the error or unexpected return of the jth index. In the second stage residuals are then used in the GARCH equation of the other indices as follows

$$r_{jt} = a + b_{j1}r_{jt-1} + \varepsilon_{jt}$$
$$\text{where, } \varepsilon_{jt} \mid \psi_{jt-1} \sim N(0, \sigma_{jt}^2) \text{ and}$$

$$\sigma_{jt}^2 = \alpha_0 + \alpha_{j1}\varepsilon_{t-1}^2 + \beta_{j1}\sigma_{jt-1}^2 + \sum_{m=1}^{k}\chi_{jk}\varepsilon_{kt}^2\sum_{n=1}^{l}\chi_{jl}\varepsilon_{lt-1}^2 \qquad [9]$$

Where, 'k' is the number of indices open/close before the jth index and 'l' which open/close after j^{th} index. For example, the modeling BSE 30 volatility, we used same day residuals of Nikkei, Kospi, STI, TSEC, KLSE, SSE, Hang Seng and JSX (these indices open/close before BSE 30)

and one day lag residuals of KSE, FTSE, CAC, DAX, NASDAQ, S&P/TSX 60 (these indices open/close after BSE 30) as used the GARCH equation. We first present the BEKK result and then the results of two stage process are presented.

We estimated the BEKK parameters through two step process. First, we modeled the bivariate VAR (BSE 30 and other Index) model, in which lag is selected based on minimum AIC criteria. Residuals obtained from the VAR model is then used for BEKK parameters estimation. Residuals of the VAR model are also tested for ARCH disturbance (Table 10) and we found that approximately all indices have ARCH effect[6].

Table 10: Results of the ARCH test on Residuals Obtained from VAR Models

Index	Close-to-close		Open-to-open	
	F value	Pr>F	F value	Pr>F
Nikkei 225	0.02	0.878	0.78	0.3775
KOSPI	2.45	0.1179	32.17	<.0001
STI	13.14	0.0003	6.98	0.0083
TSEC	39.11	<.0001	22.72	<.0001
KLSE	59.88	<.0001	22.82	<.0001
SSE Composite	6.49	0.011	3.78	0.0521
Hang Seng	4.31	0.038	0.81	0.3692
JSX Composite	16.9	<.0001	4.36	0.0369
KSE 100	2.79	0.0254	56.63	<.0001
FTSE 100	30.42	<.0001	8.86	0.003
CAC 40	26.59	<.0001	28.82	<.0001
DAX 30	28.8	<.0001	13.29	0.0003
NASDAQ	19.3	<.0001	85	<.0001
S&P/TSX 60	4.79	0.0288	6.81	0.0092

The parameter estimates of the BEKK model which explains the volatility spillover between Indian and other markets are shown in Table 11 (a) and 11 (b). Table 11 (a) shows the volatility spillover of close-to-close returns and table 11 (b) open-to-open returns. We found significant volatility spillover between India and other countries in both close-to-close and open-to-open return. It is interesting to note that most of the countries affect conditional volatility of Indian market.

While analyzing conditional volatility spillover using close-to-close return, it has been found that there exists significant volatility spillover from Hong Kong, Korea, Japan, and Singapore market to India. The parameter a_{21} is significant at 5% level. US, Germany, UK and other markets do not affect the Indian market volatility. Indian market affects (at 10% significant level) Pakistan market volatility. On the other hand open-to-open returns volatility spillover indicates that France, Korea, US, and Taiwan market affect the conditional volatility of Indian market. The parameters are significant at 5% level. Indian market only affects US market volatility in open-to-open return and the effect is negative. It means that high volatility in Indian market (BSE 30) creates lesser volatility in the US (NASDAQ) market. All other volatility spillover coefficients are positive.

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[6] In close-to-close VAR residuals, Kospi and Nikkei do not have ARCH effect and in open-to-open Hang-Seng and Nikkei do not posses ARCH effect.

Table 11 (a): Parameters Estimates of BEKK Model on Close-to-Close Return Residuals

Index->	CAC 40		DAX 30		FTSE 100		Hang Seng		JSX Composite		KLSE		KOSPI		KSE 100	
Parameters	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat
c1	0.0036	4.97	0.0034	4.94	0.0036	4.04	0.003	5.19	0.003	3.98	0.003	4.52	0.003	4.86	0.0029	3.24
c2	0.0006	2.25	0.0006	1.57	0.0004	1.51	0.0005	1.74	0.0027	1.70	0.0004	1.33	0.0012	3.14	-0.0008	-1.49
c3	0.0008	3.32	0.001	4.18	0.0008	3.37	0.0004	1.56	0.0021	1.18	0.0005	1.42	0.0006	2.06	0.0036	7.75
a11	0.3833	7.40	0.3718	7.15	0.3689	5.91	0.3595	8.29	0.3444	7.26	0.3507	7.04	0.356	7.18	0.3149	5.38
a21	0.0488	1.59	0.0276	0.80	0.0387	1.38	0.052	2.15	0.1014	2.22	0.0319	1.56	0.084	2.19	-0.0038	-0.15
a12	-0.0063	-0.44	-0.0094	-0.53	-0.0024	-0.31	0.0202	0.41	-0.0641	-0.87	0.0802	0.95	0.0234	0.53	-0.0433	-1.77
a22	0.1895	8.38	0.2108	7.85	0.2209	7.11	0.167	7.31	0.1576	3.11	0.1975	3.77	0.1659	4.02	0.4462	9.97
g11	0.8785	25.53	0.8883	26.95	0.883	20.07	0.8981	34.16	0.9197	44.33	0.9044	32.18	0.9013	31.86	0.9207	26.90
g21	-0.0217	-1.46	-0.0151	-0.87	-0.0172	-1.19	-0.0172	-1.79	-0.0365	-2.07	-0.0156	-1.63	-0.0386	-2.42	0.0155	1.03
g12	0.0039	0.67	0.004	0.54	0.0034	0.50	0.0087	0.75	-0.0329	-0.47	-0.0071	-0.43	0.0001	0.01	0.0274	1.87
g22	0.9795	188.72	0.9737	144.90	0.9712	112.32	0.9874	235.89	0.9317	22.56	0.979	72.50	0.9862	135.73	0.8425	28.37

Index->	NASDAQ		Nikkei 225		S&P 500		S&P/TSX 60		SSE Composite		STI		TSEC	
Parameters	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat
c1	0.0035	1.73	0.0031	5.20	0.0034	4.11	0.0034	4.43	0.0033	4.20	0.003	4.07	0.0032	4.90
c2	0	1.17	0.0008	2.64	0	0.10	0.0004	1.24	-0.0003	-0.19	0.0006	2.16	0.0012	3.11
c3	0.0003	0.69	0.0007	2.81	0.0006	1.94	0.0006	3.52	0.0013	0.78	0	-0.04	0.0007	2.66
a11	0.377	3.29	0.3603	7.16	0.3765	5.37	0.377	6.61	0.3611	2.33	0.3539	6.30	0.3562	6.97
a21	-0.0124	0.58	0.0631	2.05	-0.0012	-0.02	0.0427	1.04	-0.001	0.00	0.0845	3.58	0.0626	1.42
a12	0.0232	-0.69	0.002	0.07	-0.021	-0.12	-0.1496	-0.97	0.0102	0.01	0.0247	0.59	0.0062	0.19
a22	0.1597	2.16	0.1733	7.23	0.1763	6.50	0.1721	4.21	0.1758	3.35	0.1383	6.83	0.2022	6.52
g11	0.8836	6.81	0.9019	31.61	0.8885	20.84	0.8856	20.67	0.895	16.04	0.903	25.23	0.9	30.86
g21	0.014	-0.51	-0.0235	-1.75	0.0053	0.24	-0.0158	-0.68	-0.0027	-0.02	-0.0275	-2.67	-0.037	-1.92
g12	-0.0058	0.75	-0.0009	-0.10	0.0005	0.02	0.0203	0.79	0.0135	0.09	0.002	0.12	-0.0009	-0.13
g22	0.9858	66.95	0.9828	180.14	0.9815	177.65	0.9815	176.87	0.9796	28.36	0.9909	195.60	0.9774	150.93

Table 11(b): Parameters Estimates of BEKK Model on Open-to-Open Return Residuals

Index->	CAC 40		DAX 30		FTSE 100		Hang Seng		JSX Composite		KLSE		KOSPI		KSE 100	
Parameters	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat
c1	0.0024	3.54	0.0025	3.7926	0.0021	2.941	0.0025	3.302	0.0023	2.322	0.002	3.787	0.0024	3.893	0.0019	0.0019
c2	0.0004	1.26	-0.0001	-0.3157	0.0003	1.02	0.0005	1.32	0.003	0.532	-0.0001	-0.4	0.0005	1.36	-0.0002	-0.0002
c3	0.0005	1.50	0.0008	3.2719	0.0009	4.548	0.0004	1.147	0.0011	0.078	0.0004	2.079	0.0005	1.1	0.0041	0.0041
a11	0.3147	6.12	0.3248	5.6859	0.2773	4.654	0.3404	5.599	0.2524	0.598	0.3015	7.116	0.3312	6.474	0.2667	0.2667
a21	0.0464	1.77	0.01	0.448	0.0135	0.69	0.0358	1.584	0.0072	0.013	0.0045	0.36	0.0696	1.768	-0.0054	-0.0054
a12	0.0039	0.29	-0.0004	-0.0064	-0.0018	-0.031	-0.0679	-0.973	0.0702	0.143	0.0146	0.507	-0.0156	-0.772	0.0069	0.0069
a22	0.1955	7.13	0.1931	6.8873	0.2489	6.866	0.1293	5.701	0.1586	1.132	0.1946	4.958	0.1321	4.831	0.3914	0.3914
g11	0.9336	39.40	0.93	38.6839	0.9502	41.24	0.9282	32.21	0.9569	11.85	0.9437	57.23	0.9275	39.23	0.9546	0.9546
g21	-0.0181	-1.51	0.0035	0.4315	-0.0041	-0.55	-0.0065	-1.058	-0.0048	-0.041	-0.0018	-0.446	-0.0238	-1.563	0.0039	0.0039
g12	0.0048	0.89	0.0029	0.2121	-0.0004	-0.025	0.0104	0.6	-0.0445	-0.219	0.013	0.665	0.0106	1.183	0.0003	0.0003
g22	0.9806	169.41	0.9769	154.975	0.9637	101.4	0.9903	240.3	0.9475	25.62	0.9797	120.9	0.9932	186.8	0.8678	0.8678

Index->	NASDAQ		Nikkei 225		S&P 500		S&P/TSX 60		SSE Composite		STI		TSEC	
Parameters	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat	Estimates	Tstat
c1	0.0031	4.077	0.0023	4.28	0.0025	3.501	0.0028	2.395	0.0024	3.142	0.0022	4.306	0.0026	4.849
c2	0.0009	2.8383	0.0007	1.6092	0.0003	1.732	0.0007	1.263	-0.0002	-0.297	0.0002	0.88	0.0009	2.367
c3	0	0.5114	0.0006	1.9406	0.0006	2.928	0.0008	2.273	0.0023	4.557	0.0005	1.625	0.0007	1.494
a11	0.3576	6.4225	0.3102	7.2853	0.3248	5.742	0.3417	4.647	0.3015	5.244	0.3216	6.892	0.3317	7.146
a21	0.0825	3.8133	0.0332	1.1445	0.0157	0.874	0.0404	0.771	-0.0096	-0.471	0.0312	1.539	0.0924	2.995
a12	-0.1048	-2.2622	-0.0603	-1.3832	-0.0204	-0.595	-0.1236	-1.547	0.0189	0.549	-0.0497	-0.96	-0.0306	-0.662
a22	0.1771	6.132	0.1147	4.357	0.1891	6.212	0.2141	5.17	0.254	5.977	0.1811	2.994	0.1687	2.771
g11	0.9029	27.769	0.9393	54.4308	0.9313	36.74	0.9187	21.67	0.9394	37.98	0.9364	51.08	0.9286	47.08
g21	-0.0455	-2.9438	-0.0107	-1.3242	-0.0079	-1.239	-0.0239	-0.812	0.0005	0.075	-0.0076	-1.267	-0.0287	-2.152
g12	0.0215	2.049	0.0049	0.3921	-0.0029	-0.332	0.0254	1.13	0.0006	0.038	0.013	0.891	0.003	0.259
g22	0.9809	188.17	0.9909	220.569	0.9782	153.3	0.97	97	0.9553	73.38	0.983	78.63	0.9821	72.65

It is interesting to note that volatility spillover indicates the importance of openness and strength of developed markets in volatility spillover; however, geographical proximity may be a reason for volatility spillover. Contradictorily, bilateral spillover is found with US market. This result is opposite to the results of Kumar and Mukhopadhyay (2002), who found unidirectional spillover from US market to Indian market using multivariate GARCH model using data period from 1999 to 2001. This could be partly due to the difference in estimation period, as we considered the data after year 2000. They have considered overnight (NASDAQ close to Nifty open) and daytime returns (Nifty close to NASDAQ open), we have used close-to-close and open-to-open-returns. This may be the reason. Our results also contradict the results of Lee (2007), who conclude that India is less linked with Asian countries. Lee (2007) used close-to-close return and bivariate GARCH model for the data period from 1 January 1985 to 31 December 2004. Again the reason may be the difference in data period. Volatility Spillover estimated through BEKK (1,1) do not provide the partial effect of indices and also do not consider same day effect. We estimated the partial effect of indices and same day effect using univariate GARCH model as discussed earlier. The results of the parameters are presented in table 12 (a) and 12 (b).

The results of AR(1)-GARCH(1,1) model to estimate volatility spillover indicate that significant volatility spillover takes place among Asia, Europe US and Canada. Similar to the result of return spillover, volatility of particular Index is mostly affected by the indices which open just before it. Significant volatility spillover took place from US market to Japan and Korea. Japan and Korea market affect most of the Asian and European markets. Singapore, Taiwan and Hong-Kong market open/close after Japan and Korea and significant spillover take place from these markets to other Asian, European and US. The partial effects of these markets are higher than Japan and Korea. This result is consistent in both close-to-close and open-to-open return volatility spillover. London market is mostly affected by Japan, Singapore and Hong-Kong market and affects France and DAX market volatility. Significant volatility spillover takes place from Korea, Singapore, Malaysia, Taiwan and Hong-Kong to US market. It can be concluded that volatility spillover takes place from Japan and Korea to Singapore, Taiwan and Malaysia, to Hong Kong to FTSE, and DAX to US to Japan and so on. Indian market is affected by other Asian Markets and significantly affects Pakistan, German and US market.

6. Conclusions

Interdependence of emerging markets on other developed and emerging markets has great importance because strong linkage reduces the insulation of domestic market from any global shock and creates policy implications whereas weak market linkage offers potential gains from international diversifications and affects development of the emerging markets. This paper investigates long-run as well as short run integration and volatility spillover among 15 countries These countries and their representative stock index are BSE 30 (India), France (CAC 40), Germany (DAX 30), United Kingdom (FTSE 100), Hong Kong (Hang Seng), Indonesia (JSX Composite), Malaysia (KLSE), Korea (KOSPI), Pakistan (KSE 100), United States (NASDAQ), Japan (Nikkei 225), China (SSE Composite), Singapore (STI), Canada (S&P/TSX 60) and Taiwan (TSEC). Both Opening and closing prices were analyzed for the period of 1st January 2000 to 22nd February 2008. We also specifically analyzed the return and volatility spillover between Indian and other markets.

Table 12 (a) Volatility Spillover Estimates of AR(1) GARCH (1,1) Model on Close-to-Close Return of Indices

	Nikkei	Kospi	STI	TSEC	KLSe	SSE	Hang seng	Jkse	Sensex	Kse	Ftse	CAC	Dax	Nasdaq	S&PTSX60
Intercept	0.000	0.001	0.000	0.000	0.001**	0.000	0.001	0.002	0.001*	0.001*	0.00+	0.000	0.001*	0.000	0.000*
AR1	0.043	0.043	0.021	-0.015	-0.140*	0.022	-0.03+	-0.06*	-0.016	-0.046	0.087*	0.049*	0.054*	0.031	0.061*
ARCH0	0.0001*	0.00*	0.00**	0.00*	0.000*	0.000*	0.000*	0.000	0.000*	0.000*	0.000	0.000	0.000	0.000	0.000
ARCH1	0.000	0.000	0.012	0.07*	0.122*	0.215*	0.009	0.063*	0.136*	0.401*	0.019	0.017	0.016	0.017*	0.000
GARCH1	0.006	0.4125*	0.313**	0.130	0.002	0.048	0.000	0.011	0.000	0.102*	0.025*	0.000	0.008	0.000	0.597*
Nikkei (t-1)		0.000													
KOSPI (t-1)	0.000														
STI (t-1)	0.000	0.016		0.000	0.018										
TSEC (t-1)	0.000	0.027	0.000		0.000										
KLSE (t-1)	0.000	0.000	0.005	0.014											
SSE (t-1)	0.000	0.000	0.002	0.000	0.000										
Hang_Seng (t-1)	0.000	0.014	0.007	0.000	0.000	0.000									
JSX (t-1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000								
Sensex (t-1)	0.006	0.047+	0.000	0.000	0.000	0.000	0.000	0.000							
KSE (t-1)	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.009						
FTSE (t-1)	0.047	0.063	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000					
CAC (t-1)	0.031	0.076	0.010	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.019		
DAX (t-1)	0.055+	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042*	0.032*			
NASDAQ (t-1)	0.065*	0.189*	0.005	0.025	0.017*	0.000	0.060*	0.000	0.000*	0.000	0.000	0.000	0.000		
S&PTSX60 (t-1)	0.000	0.166*	0.000	0.084*	0.000	0.000	0.004	0.000	0.000	0.000	0.003	0.000	0.000	0.000	
Nikkei (t)			0.156*	0.188*	0.098*	0.059*	0.114*	0.102*	0.135*	0.012	0.118*	0.048*	0.126*	0.109*	0.000
Kospi (t)			0.130*	0.323*	0.052*	0.017	0.127*	0.139*	0.144*	0.035*	0.047*	0.031*	0.165*	0.169*	0.004
STI (t)						0.260*	0.135*	0.130*	0.156*	0.082*	0.223*	0.079*	0.103*	0.271*	0.000
TSEC (t)						0.004	0.106*	0.125*	0.134*	0.023	0.052*	0.038*	0.130*	0.209*	0.000
KLSe (t)						0.183*	0.043	0.053	0.060	0.083	0.146*	0.063*	0.036	0.206*	0.000
SSE(t)							0.020*	0.098*	0.035*	0.063*	0.019*	0.006	0.012*	0.001	0.013*
Hang_seng(t)								0.132*	0.213*	0.000	0.080*	0.063*	0.105*	0.133*	0.014
Jkse(t)									0.189*	0.055	0.088*	0.025*	0.092*	0.004	0.005
Sensex(t)										0.136*	0.038*	0.000	0.060*	0.099*	0.025*
Kse(t)											0.003	0.004	0.000	0.009	0.008*
Ftse(t)												0.693*	0.523*	0.142	0.004
CAC(t)														0.277*	0.008
Dax(t)														0.430*	0.000
Nasdaq(t)															0.106*

+(*) denotes rejection significance at the 10(5%) level

Table 12 (b) Volatility Spillover Estimates of AR(1) GARCH (1,1) Model on Open-to-Open Return of Indices

	Nikkei	Kospi	STI	TSEC	KLSe	SSE	Hang seng	Jkse	Sensex	Kse	Ftse	CAC	Dax	Nasdaq	S&PTSX60
Intercept	0.000	0.000	0.000+	0.001*	0.000+	0.000	0.000+	0.001	0.000	0.001*	0.000*	0.000*	0.001*	0.000	0.001*
AR1	0.033	0.071*	0.081*	0.078*	-0.09*	-0.028	0.048*	-0.04+	0.066*	-0.019	0.087*	0.079*	0.055*	0.057*	0.041
ARCH0	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000	0.000	0.000*	0.000*	0.000	0.000	0.000*	0.000	0.000
ARCH1	0.000	0.139*	0.010	0.036*	0.038*	0.038*	0.000	0.048	0.086*	0.288*	0.035*	0.000	0.029*	0.031*	0.000
GARCH1	0.000	0.196*	0.030	0.172*	0.022	0.000	0.000	0.000	0.002	0.187*	0.000	0.005	0.000	0.000	0.599*
Nikkei (t-1)		0.000													
KOSPI (t-1)	0.000														
STI (t-1)	0.003	0.066		0.000	0.000										
TSEC (t-1)	0.000	0.110*	0.011		0.002										
KLSE (t-1)	0.000	0.034	0.000	0.000											
SSE (t-1)	0.000	0.003	0.001	0.000	0.000										
Hang_Seng (t-1)	0.000	0.000	0.004	0.000	0.001	0.000		0.000							
JSX (t-1)	0.000	0.000	0.000	0.000	0.005	0.000									
Sensex (t-1)	0.010	0.026	0.000	0.000	0.000	0.000	0.000	0.002							
KSE (t-1)	0.000	0.013	0.000	0.004	0.000	0.000	0.000	0.000	0.000						
FTSE (t-1)	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005				
CAC (t-1)	0.008	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005		0.025		
DAX (t-1)	0.005	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.012*			
NASDAQ (t-1)	0.035*	0.106*	0.000	0.033*	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014+		
S&PTSX60 (t-1)	0.007	0.067	0.003	0.012	0.000	0.000	0.000	0.007	0.000	0.000		0.000	0.000	0.000	
Nikkei (t)			0.156*	0.193*	0.126*	0.093*	0.132*	0.141	0.122*	0.125*	0.184*	0.023	0.084*	0.048	0.007
Kospi (t)			0.293*	0.498*	0.100*	0.026*	0.190*	0.204	0.175*	0.014	0.011	0.110*	0.121*	0.239*	0.000
STI (t)						0.563*	0.304*	0.157	0.134+	0.000	0.121*	0.099*	0.081*	0.120*	0.000
TSEC (t)						0.000	0.088*	0.112+	0.168*	0.007	0.081*	0.103*	0.127*	0.209*	0.000
KLSe (t)						0.192*	0.135*	0.074+	0.089*	0.004	0.043+	0.077*	0.015	0.156*	0.000
SSE(t)							0.071*	0.151*	0.037*	0.090*	0.006	0.003	0.000	0.000	0.010*
Hang_seng(t)									0.186*	0.000+	0.118*	0.152*	0.091*	0.230*	0.006
Jkse(t)							0.161*		0.209*	0.036	0.098*	0.020	0.077*	0.046	0.000
Sensex(t)										0.130*	0.012*	0.022*	0.072*	0.028*	0.019*
Kse(t)											0.031*	0.000	0.000	0.025*	0.008*
Ftse(t)												0.664*	0.219*	0.164*	0.000
CAC(t)														0.399*	0.005
Dax(t)														0.117*	0.000
Nasdaq(t)															0.104*

+(*) denotes rejection significance at the 10(5%) level

Most of the work in this area either uses the CCF test developed by Cheung and Ng (1996) to estimate the correlation between returns and volatility or VAR model up-to 5-6 variables (method used to calculate the effect of past return/volatility). The investigation of contemporaneous (co-movements) and dynamic (causation) information spillover is limited. However, it is important to use contemporaneous returns (volatility) when their opening and closing times are different (Kim, 2005; Lee, 2007). Generally, developed market (US, Japan and European markets) are used as exogenous (control) variable. However in current economic (trade) and financial liberalization (FII and Dual listing) scenario, it is plausible that the emerging markets may affect the developed markets. Application of VAR-BEKK model in estimation of volatility spillover is also limited. In this paper vector autoregressive model in which all 15 indices are used as endogenous variable to estimate the effect of one day lag returns. Application of higher order VAR model is rare. The contemporaneous (co-movements) and dynamic (causation) information spillover is estimated using univariate (AR and AR-GARCH) models. The bivariate VAR-BEKK model is also applied to estimate volatility spillover to-and-from Indian market to other markets.

It is found that most of the Asian indices are influenced by lag returns of European and US indices. This result is partial because of the fact that the influencing indices close/open after all Asian indices and the same day effect is ignored in the VAR model. Results are different when univariate model is used and same day effect is incorporated in the model. We found that return spillover takes place from US market to Japanese and Korean market to Singapore, Taiwan market to Hong-Kong to European market to US and so on. However, some of the Asian markets like that of Japan, Korea, Singapore, and Hong-Kong markets show more influencing power than other Asian Markets. The European Markets are mostly influenced through Japanese, Korean, Singapore, Hong-Kong market and US market. A high correlation among European countries is also observed. US market is influenced by both Asian and European market. Volatility spillover is also analyzed through two-step AR-GARCH process. The same day effect is considered in the model. We found the similar result as we found in the case of return spillover.

In contrast to Ng (2000) results but similar to Miyakoshi (2001), we found greater regional influence among Asian return and volatility than European and US. Japanese market is affected by US and European market and affects most of the Asian Market. This finding is similar with the finding of Chuang et al. (2007) who analyzed six Asian markets including Japan and found that Japanese market is the least susceptible to volatility stimuli from other markets, however, is the most influential in transmitting volatility to the other East Asian markets. Also, we found high degree of correlation among European indices namely FTSE, CAC and DAX, which support the similar finding of many works (Cheung and Westermann, 2001; Melle, 2003; Savva et al., 2004 and Bartram et al, 2007) that analyzed these indices after introduction of EURO.

Interdependence of Indian market with other world market is analyzed separately. We do not find any cointegration of BSE 30 with any major index except JSX composite closing prices, which indicates that the investor may benefit from international diversification. Short-run relationship is investigated through Granger Causality test and parameters are estimated through VAR models. We found significant two-way Granger causality of Indian market with US, Japanese, Korean, and Canadian and significant positive return spillover. This contradicts the results of Nair and Ramanathan (2002) and Kumar and Mukhopadhyay (2002) who found that

there is unidirectional return and volatility spill from US market to Indian market. This may be because of the selection of period and kind of return considered for analysis. We have considered close-to-close and open-to-open return for analysis, however Kumar and Mukhopadhyay (2002) considered overnight (NASDAQ close to Nifty open) and daytime returns (Nifty close to NASDAQ open) to estimate volatility spillover using bivariate GARCH model. It was also found that France, United Kingdom and Hong, Kong positively affect Indian market but are not affected by Indian market. Indian market affects positively German, Indonesian, Korean, Pakistan, US, Japanese and Taiwan market. It is important to note that Chinese market is not influenced by Indian market nor influences it.

Along with AR-GARCH model, we also applied multivariate GARCH (BEKK) model approach to analyze conditional volatility spillover between Indian market and other fourteen markets. We observed that there also exist positive volatility spillover between Indian market and Hong Kong, Korean, Japanese, US and Singapore market. However, Indian market affects negatively the conditional volatility of US and Pakistan market. These results contradict that of Lee (2007), who analyzed volatility spillover among six Asian countries including India and found less linkages of Indian market with Asian countries.

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