Chapter 6
A Study on the Spillover of Stock Market Volatility between India and US in the Context of the Global Financial Crisis of 2007–08

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6.1 Introduction

With the advent of globalization, as the financial rules and regulations have gradually been softened, the financial markets worldwide have become more and more interlinked. The explosion of advanced communication technology has made the rapid transmission of market information possible within and across markets of different countries all over the world in a very short span of time. This phenomenon is more prominent in the financial sector, especially in the stock market, which is very sensitive in nature being one of the most important and active components of the financial sector of any economy. Any information, originating domestically or internationally, that can make a stock market volatile, can affect investment, which in turn can lead to a sequence of reactions influencing corporate financing, market risk and ultimately financial stability of an economy. The recent global financial crisis, which actually originated in the US realty sector, gradually took a massive dimension and contaminated almost every country worldwide—either developed or emerging in different intensity and scale. This widespread crisis created massive turmoil in the stock markets through spillover of return and volatility of the US markets via different channels like trade channel, financial channels and confidence channels. Such interlinkages have drawn the interest of the researchers to explore this area to analyse the intrinsic behaviours of the stock markets.

There exist several studies addressing extensively these interrelated issues. However, very few works have focused on the intermarket relationship within the Indian financial market around the recent global financial crisis. In such a scenario,

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this study is a humble attempt to explore the dynamic pattern of interlinkages between the Indian stock market and the stock market of US in terms of volatility spillover, around the financial crisis of 2007–2008. The intrinsic nature of spillover is analysed between the two stock markets under an intercountry structure. In order to examine the impact of the crisis on the intermarket volatility spillover relationship between the two mentioned stock return series, the study intends to estimate as well as compare the nature of the stock market behaviour in terms of volatility prior to the crisis, during the crisis and after the crisis.

6.1.1 Global Financial Crisis of 2007–08

The subprime crisis, that originated in the US realty sector during 2005–06 as an isolated turbulence gradually metamorphosed to the worst recession that the world has faced since the Great Depression of the 1930s. Though the subprime crisis was caused by complex and interlinked factors, the main triggering factor was the faulty banking system offering high-risk subprime loans. This practice along with the slack monetary policy, misperception of risk and lax financial regulation formed financial bubbles in 2001–02. Low-interest rate prevailing in the housing sector drew attention of the countries like the UK, Japan and China causing a huge inflow of foreign capital. During 2005–06, the bubble burst and initiated the crisis. Gradually, the crisis spread to other countries and eventually took the shape of a global financial crisis in the last quarter of 2007 and continued for about eighteen months.

6.1.2 Impact of the Crisis on the US

The US economy had to undergo a run down with continuous fall in the value of property and increase in foreclosure and defaulter rate. The banks and top investment firms were either bankrupt or declared as ailing. With the collapse of Lehman Brothers, Bears Sterns and the others during 2008, the situation worsened. Confidence of the investors on the stock market dropped and the market crashed due to a huge outflow of fund. It is revealed from the data set under study that NASDAQ was crashing phenomenally and even hit a trough at around 1300 points in March 2009. US Federal Government intervened with several stabilization measures and a magnum bail-out scheme. These measures could to some extent arrest further economic and financial massacre and initiate a reverse pattern.

6.1.3 Impact of the Crisis on India

Indian financial market, though well governed and did not have much direct exposure to the US assets, it could not protect itself from the virus of the crisis.

In fact, disruptions of international money markets, turmoil in stock markets across the globe and severe investor pressures impacted the Indian money, forex and stock market. The stock market experienced a severe and rapid downfall, which gradually created a panic in the market. On 24th October 2008, Sensex lost 1000 points as Rs. 250,000 crores was withdrawn from the share market on a single day. FIIs made a withdrawal of 5.5 billion US dollar during April–September 2008. Indian rupee depreciated approximately by 20% against US dollar. Export dropped to 1.5 billion dollar in November, 2008 from 12.7 billion dollars in the previous year causing an intense trade deficit. RBI intervened to maintain orderly conditions in the foreign exchange market and to address the liquidity pressures through a variety of measures like reducing repo rate, reverse repo rate, Cash Reserve Ratio, Statutory Liquidity Ratio, etc. (Thorat 2009). The positive impact of all these measures was reflected in the Indian stock market returns as well.

This paper focuses on the interaction between the stock markets of US and India in terms of volatility spillover covering the period of the 2007–08 financial crisis episode. The results of empirical estimation on market behavioural changes are discussed with intuitive interpretation in the backdrop of the market functionalities and profiles of the countries concerned. Rest of the paper is organized as follows. Section 6.2 documents a brief overview of the existing literature on this issue. Section 6.3 explains the methodology applied for investigating stock market volatility spillover. Section 6.4 analyses and discusses the empirical results estimated and finally, Sect. 6.5 concludes the study.

6.2   Literature Review

With growing international financial transactions and capital flows across financial markets, transmission of information generating probabilities of unpredictable shock and creating heightened market sensitivities became a major cause of concern. Relatively earlier studies mostly discuss interaction and co-movement among the markets while spillover of market volatility gained more importance later.

On the interaction and co-movement among the markets, Becker et al. (1990) observed significant influence of the performance of the US stock market on the Japanese stock market whereas the reverse impact was negligible as expected. Karolyi and Stulz (1996) exhibited predictable patterns in the US and Japanese cross-country stock return covariances but did not find any evidence of either macroeconomic announcements or interest rate shocks affecting the comovements between their stock returns. Longin and Solnik (1995) investigated whether the conditional correlation in international asset returns is changed due to the progressive interdependence across markets of France, Germany, Switzerland, Canada, Japan, US and UK. Morgado and Tavares (2007) examined the consequences of real and monetary integration on the correlation of real stock returns of forty countries and found that countries with more developed and more analogous

institutions display a higher correlation of stock returns. Considerable equity market interlinkages during the 1980s are evidenced in Daniel (2000) and Robert and Luc (2002).

Including India among other countries, Rao and Naik (1990) observed that the relationship of the Indian market with international markets is not quite prominent as the Indian economy is characterized by regulations throughout the entire period of their study. Considering UK with US and India, Sharma and Kennedy (1997) concluded that stocks listed on the Bombay Stock Exchange follow a random walk. A later study observed that the Indian stock index and the matured stock indices of US, UK and Japan are found to form fractionally co-integrated relationship in the long run (Wong et al. 2005). Similarly, studies by Hansda and Ray (2003), Mishra (2002) and Nair and Ramanathan (2003) evidenced a synchronized movement of BSE and NASDAQ. The existence of only a short run comovement of prices among Indian and other national equity markets of Asia, Europe and America are observed in Mukherjee and Mishra (2005). Bose and Mukherjee (2006) examined the interlinkages of eight Asian stock markets, including India, with the US stock market during 1999–2004, highlighting the 'unique role of India' with more open capital market encouraging cross-market capital flows. However, Nath and Verma (2003) did not find any evidence of cointegration among the three major stock markets in South Asia viz. India, Singapore and Taiwan during 1994 and 2002. In another study, the stock markets of India and six other developed countries including US and Japan are found to move in tandem in post-financial liberalization era (Nath 2003). Sarkar et al. (2008) found unidirectional causality from the stock markets of US, UK, Jakarta and Argentina to India and a bidirectional causality between Brazilian and Indian stock markets.

With gradual increase in cross-country interlinkage through various channels, working of the international transmission mechanism, particularly volatility spillover, appeared more important. Studies on the spillover of market volatility are mostly empirical in nature. The countries chosen in different studies for volatility spillover are based on several aspects like whether they are trading partners, their geographical location, their development status, etc. United States having consistent dominance over others has been commonly chosen among others in most of the studies.

Hamao et al. (1990), Kee-Hong and Karolyi (1994) explored US, UK and Japan stock markets and observed that New York daytime returns significantly influence other market returns and there exists cross-market interdependence within return series in terms of spillover of volatility. A study by Li and Giles (2015) revealed significant unidirectional shock and volatility spillovers from the U.S. market to the Japanese and the Asian markets during the Asian financial crisis. Evidence of return spillover effects from both domestic and foreign market along with significant volatility spillover effects only from foreign market are found in Kumar and Mukhopadhyay (2002, 2007). Studies by Gunasinghe (2005), Mukherjee and Mishra (2006), Joshi (2011) revealed bidirectional return and volatility spillover effect among almost all Asian stock markets including India.

Literature on the recent subprime crisis of 2007–08 highlight strong evidences of stock market volatility spillover from USA on different countries. To mention a few, are the works by Olowe (2009) for Nigeria, Anaraki (2012) for Europe, Chinzara (2011) for Africa, Zhang et al. (2011) for China, Karunanayake et al. (2010) for Australia, Singapore and UK, Parsva and Lean (2011) for 6 Middle Eastern Countries. Similar result surfaces in studies by Ali and Afzal (2012), Gangadharan and Yoonus (2012) and Manda (2010) which include also India. However, studies by Chong (2011) for China and Schwert (2011) for UK and Japan observed that though the negative effect of financial crisis transmitted to other countries, the effect was short-lived.

A deeper study on the 2007–08 crisis phenomenon investigating the changing pattern of spillover of the stock market return and volatility from Pre-Crisis to In Crisis to-Post-Crisis scenario appears to be an important aspect not addressed adequately in the existing literature. The contribution of this paper harps on analysing the changing stock market behavioural patterns over the three sub-periods in the backdrop of the then existing economic scenario of the chosen countries. Market performances are investigated through own and cross means return spillover, own and cross volatility spillover and the asymmetric effects of information spillover under intercountry structural setup.

6.3   Data and Methodology

For examining the dynamic relationship in terms of volatility spillover between the stock markets of India and USA, daily closing data of BSE SENSEX and NASDAQ Composite, from Jan 1, 2004 to September 13, 2013, are selected (www.finance.yahoo.com). A total of 2189 observations are considered for which the respective close-to-close trading periods in India and the US are perfectly aligned.

Daily return series (close$_{t-1}$ to close$_t$) are derived for each stock market as the first difference between the log of closing prices on consecutive trading days, expressed in percentage terms:

$$R_t = \ln\left(P_t/P_{t-1}\right) * 100, \text{ where}$$
$$R => \text{Daily return of BSE and NASDAQ};$$
$$P => \text{Closing price of BSE and NASDAQ};$$
$$t = 1, 2, 3, \dots, N;$$
$$N => \text{number of observations.}$$

The stationarity of the variables is examined by performing Augmented Dickey–Fuller test (Fuller 1976; Dickey and Fuller 1979, 1981) as shown below:

$$\Delta y_t = \alpha + \varphi T + (1-\beta) y_{t-1} + \sum \lambda_i \Delta y_{t-j} + \varepsilon_t,$$

Where y_t is the variable tested for unit root; Δ is the first difference operator; α is the constant term and T is a time trend.

Thus, the null hypothesis to be tested is

H_0: $(1-\beta) = 0$, $\beta = 1$, i.e. series contains a unit root.

Rejection of null hypothesis implies that the time series is stationary.

To analyse the impact of financial crisis on the spillover relationship among the stock markets, the study divides the entire data set into three sub-periods, namely Pre-Crisis, In Crisis and Post-Crisis.

Pre-Crisis—from 05/01/2004 to 9/10/2007 (856 observations)

In Crisis—from 10/10/2007 to 9/3/2009 (314 observations)

Post-Crisis—from 10/3/2009 to 13/9/2013 (1019 observations)

Initially, correlation coefficients between the relevant market returns are estimated. Our study explores behaviour of each stock market under an intercountry structure. The impact of the global financial crisis in terms of volatility spillover on the return series of BSE and NASDAQ is examined under own and cross-market set up. For estimation, a Multivariate GARCH model is used. Specifically, the study applies Diagonal VECH model (DVECH model) which is an extension of the basic univariate GARCH model. Bollerslev et al. (1988) first proposed a general VECH model in which each element of H_t is a linear function of the lagged squared errors and cross products of errors and lagged values of the elements of H_t. The presentation of the general VECH model is:

$$\text{vech } (H_t) = M + A \text{ vech } (\varepsilon_{t-1}\varepsilon'_{t-1}) + B \text{ vech } (H_{t-1})$$

Where the vech(.) operator stacks the lower triangular portion of a symmetric matrix into a vector.

Here, A and B are $[(N (N + 1)/2) \times (N (N + 1)/2)]$ parameter matrices and M is a $[(N (N + 1)/2) \times 1]$ vector of constants.

However, the limitation of this model is the large number of parameters that need to be estimated. The number of parameters is $[n(n + 1) (n(n + 1) + 1)/2]$. Additionally, it is difficult to guarantee the positivity of H_t without imposing strong restrictions on the parameters (Gourieroux 1997). To overcome this problem, Bollerslev et al. (1988) suggested the diagonal VECH (DVECH) model in which the A and B matrices are assumed to be diagonal, and this restriction reduces the number of parameters to $[n(n + 5)/2]$.

The diagonal elements of matrix A (a_{ij}, where $i = j$) represents the own market past innovation effect on current volatility, i.e. own mean spillover effect. Similarly, the off-diagonal elements a_{ij}, where $i \neq j$, measures cross mean spillover effect on current volatility, i.e. the effect of country i's (or j's) shock on country j's (or i's) volatility. On the other hand, the diagonal elements of matrix B (b_{ij}, where $i = j$) explains own volatility spillover effect where the off-diagonal elements (b_{ij}, where $i \neq j$) give cross volatility spillover effects.

To capture the asymmetric news effect on volatility spillover, the model is extended by incorporating a threshold term in the variance–covariance matrix to

examine whether market volatility reacts more vigorously to a 'bad news' than to a 'good news' of same magnitude.

The specific DVECH model takes the following form:

$$\text{vech}\ (H_t) \ = \ M \ + \ A\ \text{vech}\ (\varepsilon_{t-1}\varepsilon'_{t-1}) + B\ \text{vech}\ (H_{t-1}) \ + \ D\ \text{vech}\ (\varepsilon_{t-1}\varepsilon'_{t-1})$$

D: A dummy matrix to capture the asymmetric news effect on volatility spillover

$$D = \begin{cases} 1 & \text{if}\ (\varepsilon_{t-1} < 0) \\ 0 & \text{otherwise} \end{cases}$$

The parameter matrix D has a similar expression to the matrix A. However, the parameters in the matrix D measure the asymmetric response to the negative shocks or 'bad news' vis-a-vis positive shocks or 'good news'.

This particular model is apt to capture the asymmetric effect of different types of information on volatility along with mean and volatility spillover. The system developed for the intercountry analysis is given as follows:

$$BSE(t) \ = \ C(1) + C(2) * BSE\ (t-1) + C(3) * NAS\ (t-1)$$
$$NAS\ (t) \ = \ C(7) + C(2) * BSE\ (t-1) + C(3) * NAS\ (t-1)$$

6.4   Findings and Discussions

6.4.1   Preliminary Tests

The results in Table 6.1 suggests that all variables are stationary of order 0, with trend as well as without trend, which confirms the applicability of the data set for analysis.

Table 6.2 which reports the descriptive statistics for the two stock returns for the three sub-periods, Pre-Crisis, In Crisis and Post-Crisis, establishes that before the advent of the crisis mean return is positive for both the stock return series which becomes negative as the crisis strikes out. Again, when the crisis is over, mean return becomes positive. The standard deviations of all the return variables almost double up during the crisis period as compared to the Pre-Crisis period, which again

Table 6.1 Stationarity test results

Return series	ADF without trend	ADF with trend	Result
BSE	−44.16942	−44.17241	Stationary
NAS	−50.61202	−50.60720	Stationary

Source Stock market data are collected from www.finance.yahoo.com. ADF test critical values are at 1% level = −3.4378, 5% level = −2.8647 and 10% level = −2.5685, *significant at level 10%, **significant at level 5%, ***significant at level 1%

Table 6.2 Descriptive statistics of the return series

	BSE SENSEX			NASDAQ		
	Pre	In	Post	Pre	In	Post
Mean	0.1342	−0.2568	0.0866	0.0362	−0.2525	0.1056
Median	0.2046	−0.3105	0.0705	0.0891	−0.1661	0.1257
Maximum	7.9310	8.6878	15.9899	3.8169	9.5744	11.6998
Minimum	−11.8091	−12.7959	−4.4456	−3.9358	−9.5877	−7.9635
Std. Dev.	1.5311	2.8817	1.4131	0.9903	2.5348	1.4076
Skewness	−0.8159	−0.1722	1.8120	−0.1809	−0.3174	0.1188
Kurtosis	9.4403	4.6788	20.912	3.7810	5.1135	10.4939
Jarque–Bera	1574.36	38.43	14181.50	26.3698	63.7135	2386.85
Probability	0.000	0.000	0.000	0.0000	0.0000	0.0000

Source Stock market data are collected from www.finance.yahoo.com. [*]significant at level 10%, [**]significant at level 5%, [***]significant at level 1%

Table 6.3 Correlation coefficients of the return series

	BSE			NASDAQ		
	Pre	In	Post	Pre	In	Post
BSE	1.0000	1.0000	1.0000	0.1888	0.3602	0.3258
NASDAQ				1.0000	1.0000	1.0000

Source Stock market data are collected from www.finance.yahoo.com. [*]significant at level 10%, [**]significant at level 5%, [***]significant at level 1%

decreases when the crisis is over indicating upsurge of volatility during the crisis. All series are found to be non – normal, skewed and with fat tails as kurtosis is greater than three. Further, the Jarque–Bera normality test ($p < 0.001$) reveals a statistically significant deviation of the data from normality.

In all the three sub-periods in Table 6.3 the stock return series are found to be positively correlated with each other with the coefficients increasing during crisis period for all cases confirming the fact during a panic situation markets move in tandem.

6.4.2 Intercountry Volatility Spillover Analysis

The impact of the global financial crisis on the BSE and NASDAQ return series are analysed simultaneously within a single structure under an intercountry set up. The study examines the effect on the volatility of return series of own mean spillover, cross mean spillover, own volatility spillover, cross volatility spillover, asymmetric own information spillover and asymmetric cross information spillover. The results for applying Multivariate VECH model is presented in Table 6.4.

Table 6.4 Results of volatility spillover analysis under the Inter Country structure

	PRE		IN		POST	
	BSE	NASDAQ	BSE	NASDAQ	BSE	NASDAQ
	Coefficients					
BSE	0.1096 (0.00)***	0.0157 (0.11)	0.6915 (0.03)**	0.2701 (0.30)	0.0193 (0.00)***	0.0113 (0.00)***
NASDAQ		0.0348 (0.00)***		0.2547 (0.04)**		0.0589 (0.00)***
	Arch effect					
BSE	0.0685 (0.01)	−0.0629 (0.00)***	0.0007 (0.96)	0.0451 (0.48)	0.0201 (0.01)**	−0.0128 (0.15)
NASDAQ		−0.0314 (0.01)**		0.0385 (0.48)		−0.041 (0.00)***
	Garch effect					
BSE	0.8380 (0.00)***	0.9018 (0.00)***	0.7949 (0.00)***	0.5988 (0.02)**	0.9410 (0.00)***	0.9432 (0.00)***
NASDAQ		0.9401 (0.00)***		0.8518 (0.00)***		0.9039 (0.00)***
	Asymmetric news effect					
BSE	0.0707 (0.04)**	0.0760 (0.02)**	0.2254 (0.00)***	0.1822 (0.17)	0.0524 (0.00)***	0.0337 (0.00)***
NASDAQ		0.1068 (0.00)***		0.1337 (0.08)*		0.1711 (0.00)***

Source Stock market data are collected from www.finance.yahoo.com. *significant at level 10%, **significant at level 5%, ***significant at level 1%

6.4.2.1 Own Mean Spillover Effect on Volatility of Return Series

BSE Return Series

During the Pre-Crisis and the In Crisis periods, no observable significant mean spillover effect is found in BSE return series volatility in the intercountry structure. Hence, past return values of BSE are not sufficient to explain own volatility during these two periods. The total effect coming from the sources other than BSE return series has become so significant that it has perhaps outweighed the own return spillover effect on volatility. During the In Crisis period also, the massive impact of the crisis has overshadowed the influence of the previous return values of BSE to determine its current volatility.

However, as the period of the crisis was over, past return values of the BSE return series became significant at 5% level to determine current volatility. During this period, the policy packages undertaken to stabilize the economy came into operation. These were credit easing and 'actual/potential liquidity augmentation' (Thorat 2009) and other measures which worked towards invigorating the financial market. The market players were regaining their confidence on the Indian financial

markets and financial portfolios of the investors were being rearranged. Interdependence between the past return values of BSE with own present volatility reappeared in the intercountry model. Hence as the analysis gradually advances from the Pre-Crisis to the In Crisis and then to the Post-Crisis period, nature of BSE own mean spillover changes noticeably in the intercountry set up.

NASDAQ Return Series

The role of the past return values of NASDAQ to determine its current volatility varied noticeably over the different phases of the crisis in the intercountry structure. Before the advent of the crisis, past return values emerged as a significant factor to explain current volatility but it became insignificant during the In Crisis period. Again, in the Post-Crisis period, as the crisis started to subside, own mean spillover effect became significant like the Pre-Crisis period. The vast investor base of the NASDAQ stock index, the composition of this stock index with foreign enlisted companies and its interconnectedness with other markets are the factors operating behind these. Thus, the market players were so concerned about the performance of NASDAQ market that its past return values were considered with importance in the Pre-Crisis period.

With the breakout of the crisis, this mean-volatility relationship no more remained self-explanatory. The huge and severe impact of the crisis created panic in the minds of the market players in such a way that the impact of the previous values of the return series on the volatility of NASDAQ became blurred.

During the period, the US Government took several stabilizing policies to rescue the economy from the adverse effects of the crisis. In 2008, the Troubled Asset Relief Programme (TARP) was undertaken to purchase assets and equities from the ailing institutions, which saved General Motors and Chryslers from bankruptcy. The American Recovery and Reinvestment Act (ARRA 2009) helped to create new jobs and boosted the economic growth. A financial Regulation Bill was passed in 2010 along with restoring the American Financial Stability Act addressing the risky behaviour and the regulatory failures of the Federal economy. Thus, the immediate intervention of the Federal Government in the form of 700-billion-dollar bailout package could rescue the Citi Group, JP Morgan and other ailing investment firms. NASDAQ gradually started to recover and in May 2013 it touched a record high at around 3000 basic points. The impact of the global financial crisis on the US foreign exchange market was varying. From 2007 to the middle of 2008, the demand for US currency decreased which started to increase thereafter (www. federalreserve.org/).

The results of these policies were being realized during the Post-Crisis period. The US financial market started to regain its lost confidence. The national and international market participants started to depend on the past values of the NASDAQ return series to explain its current return volatility. Hence, significant mean spillover is observed in our study during this Post-Crisis period.

6.4.2.2 Cross Mean Spillover Effect on Volatility of Return Series

BSE versus NASDAQ Return Series

The estimated result indicates the presence of significant cross return spillover of the volatility between BSE and NASDAQ during the Pre-Crisis period only. During the In Crisis and the Post-Crisis periods, this effect is found to be insignificant. As NASDAQ is one of the most active stock markets of the world and has market interaction with India, the performance of NASDAQ in the Pre-Crisis period had influenced the sensitivity of the market players of BSE.

Interestingly, when the crisis hit the global economy and disrupted other economies through trade, financial and confidence channels, the international financial market players lost the confidence on the market and were driven by the crisis panic. The interlinkage between the stock markets through the mean spillover channel thus broke down temporarily as the panic factor dominated the normal market activities.

As revealed in the In Crisis case, no evidence of cross mean spillover effect between BSE and NASDAQ is noticed during the Post-Crisis period also. The US being the epicentre of the crisis, it took time to normalize the situation there completely. Though the countries started to regain their regular pace in every sector, the interaction between NASDAQ and BSE could not become strong enough to reflect the mean—volatility relationship between these two markets in this period.

6.4.2.3 Own Volatility Spillover Effect on Volatility of Return Series

BSE and NASDAQ Return Series

During all the three periods under study, the presence of significant own volatility spillover in both BSE and NASDAQ return series is revealed which indicates that volatility of each return series is reflected in the following period's volatility. As the period of study covers the financial crisis episode, panic created in the market is seen to be reflected in the own volatility spillover of the return series.

6.4.2.4 Cross Volatility Spillover Effect on Volatility of Return Series

BSE versus NASDAQ Return Series

For all the cases considered, the results reveal that there exists a significant cross volatility spillover between BSE and NASDAQ. Following financial globalization, cross-market interlinkages being already in operation for quite some time expressed itself during the crisis episode in the form of pronounced volatility spillover across markets.

6.4.2.5 Asymmetric Own Information Spillover Effect on Volatility of Return Series

BSE Return Series

The study observes evidence of significant asymmetric information spillover effect in the volatility of the BSE return series during all the three periods—Pre-Crisis, In Crisis and Post-Crisis. The sign of asymmetry is found to be positive, which implies that, significant leverage effect existed in the BSE return series over the study period, where bad news or negative information increased the volatility of BSE return series more as compared to the rise in the volatility due to a good news or positive information of the same magnitude.

India is fundamentally a strong country with regulated financial markets and BSE is also a well-functioning stock index. Without any severe economic abnormality, the market participants have confidence on this market and they adjust their financial position according to the available information. Therefore, under the normal market conditions, bad news had more impact on the volatility of the BSE return series compared to good news during the Pre-Crisis period.

The information of the crisis made the volatility of BSE more vulnerable to bad news as significance level increased from 5% level to 1% level from Pre-Crisis to In Crisis period. In a panicked situation, the market participants became more sensitive to the bad news arriving in the market. So, the asymmetric effect of white noise to the BSE return series is found to be more significant during the In Crisis Period.

During the Post-Crisis period, the stabilizing measures and policies adopted by the Indian authorities helped the market to overcome the adverse impacts of the crisis. The market participants started to regain their confidence on BSE soon. However, under the open system, world information in the aftermath of the crisis had a greater role to play. For this reason, in this Post-Crisis period also the asymmetric effect of white noise to BSE return series is found to be highly significant.

NASDAQ Return Series

In the intercountry structure, significant asymmetric information spillover effect is found on the volatility of NASDAQ and the sign is positive during all the three sub-periods under study.

NASDAQ being a strong and active stock exchange linked with several other national and international financial markets, it is highly influenced by new news or any random shock. Thus, in the Pre-Crisis period, the asymmetric news spillover effect to the volatility of NASDAQ return series is found to be significant and positive.

As the crisis hit the US economy, the US financial market was flooded with loads of information related to the crisis sourced from the domestic economy as well as from the reaction of the markets of other countries to this event. The internal information like bankruptcy of Lehmann Brothers, etc. adversely affected the

sentiments and confidence of the market players and made them panicked. Along with this, the panic reaction of other countries was also important. As any new information was considered with awareness in a state of panic, the level of significance of negative news on the volatility of NASDAQ decreased from 1% during the Pre-Crisis period to 10% during the In Crisis period.

During the Post-Crisis period, the US Government was implementing recovery measures to bring back stability in the economy. The market players started to regain their lost confidence. However, the market remained more sensitive to bad news in the open system and paid more attention to the negative news compared to the positive news of the same magnitude to cover the losses made during the crisis. This is reflected through significant asymmetric information spillover effect during this time.

6.4.2.6 Asymmetric Cross Information Spillover Effect on Volatility of Return Series

BSE versus NASDAQ Return Series

In the Pre-Crisis period, there existed significant asymmetric cross information spillover between the volatility of BSE and NASDAQ return series, i.e. any bad news from one return series affected the volatility of the other return series significantly more as compared to the effect of good news of similar magnitude.

During the In Crisis period, the crisis panic made the market players too responsive to any new information irrespective of the nature of the information—good or bad, resulting in the increased market volatility. Therefore, significance of the asymmetric effect faded out.

When the crisis was over, the cross-asymmetric information spillover became significant again like the Pre-Crisis period as the market relations were tending to return to the normal situation.

Thus, the significance of the cross information spillover between the return series of BSE and NASDAQ is found to be varying through different stages of the crisis.

6.5 Concluding Observations

This paper examines the dynamics of volatility spillover of the selected return series of the stock indices of India and US in an intercountry analytical set up around the global financial crisis of 2007–08 applying the multivariate Diagonal VECH Methodology. The econometric results are explained considering the economic profiles of the concerned countries and interlinkage among the concerned stock markets. In general, both the markets are found to experience significant own and

cross volatility spillover effect during all the three sub-periods, which implies that volatility spillover across markets is quite prominent, compared to return spillover. In addition, the significant cross volatility spillover in all the cases considered indicates the global feature of financial market volatility spread. The onset of financial crisis of 2007–2008 is the main catalyst behind such outcome. The study finds strong evidence of news asymmetry contributing significantly to the volatility spillovers both within and among BSE and NASDAQ stock returns during all the three periods. Thus, this research observes that the crisis panic disrupted the usual stock market activities of the two countries studied here and affected their stock market relationships through interaction among the financial markets and their responses to the changing global scenario. The nature of market interaction has considerable bearing upon the economic and financial planning of any economy, framing of corporate strategies and investors' decision making.

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