CHAPTER 6: MEASURING CONTAGION-2  
(A TIME VARYING COPULA APPROACH)

6.1 INTRODUCTION

The previous chapter examines the contagion from US stock markets to selected Asian stock markets by using DCC GARCH and ADCC GARCH method. The results show that most of the countries have contagion effect from the US stock market during the Sub-prime crisis of 2007-08. DCC GARCH results imply that the Japanese stock markets disassociate with the US stock markets post the financial crisis. The ADCC GARCH results show that the Taiwan stock markets do not have much correlation with the US stock market after it was hit by the housing bubble. The DCC and ADCC GARCH models cannot be used if the series is non-linear in nature. Both the methodologies are suitable for the series which are linear in nature. The ADCC methodology also considers the impact of positive as well as negative news in the market. Thus, the issue of interdependence and contagion of financial markets has always been issue of interest for the financial economists and investment advisors (Bartram et al., 2001; Bartram et al., 2007). The study on interdependence and contagion has particularly gained considerable attention in the literature due to its implications on asset allocation and portfolio diversification. Researches in recent times have provided mixed results on contagion in equity markets (Labidi and Anne, 2007; Jondeau and Rockinger, 2006; Bekaert et al., 2005; Poon, Rockinger and Twan, 2004; Longin and Solnik, 2001, Forbes and Rigobon, 2002). However, these studies have usually examined contagion in developed nations like US, UK, Germany, France and Japan. Hence, the focus of the present study is to examine contagion effect between the US stock market and the stock markets of the Asian stock markets during the Sub-prime crisis period using Copula methodology.

There are two possible explanations for non-consciences evidence on contagion. One, the researchers have still not been able to arrive at one single definition of contagion, accepted by all. Second, various researchers have examined contagion in financial markets during crisis using different methodologies, and hence have arrived at contradictory results. Several researchers have examined contagion among various financial markets, whether neighboring or distant; during crisis period by analyzing
cross market correlations (Aloui et al. 2011; Cappiello et al., 2006; Kim, 2005; Marcel et al., 2011, Phylaktis and Ravazzolo, 2005). Many researchers have followed the definition by Forbes and Rigobon, 2002 and have found mixed results (Ang and Bekaert, 2007; Chiang et al., 2007; Lessard, 1973). Much of the focus of previous studies on contagion has been on providing evidence of significant increase in cross market correlations between equity markets and volatility in the region (Chiang et al., 2007). There are many limitations of examining contagion through analyzing correlation. Due to increased volatility in the equity market during a crisis, cross market correlations may be biased upwards. Increased correlation coefficient may be induced by heteroskedasticity, which biases the contagion tests (as during turmoil, volatility of any market increases as compared to tranquil period) (Ahlgren and Antell, 2010). To overcome the limitations evident in the literature, in this study time varying copulas (Wen et al. 2012; Bastianin, 2009; Westner and Madlener, 2012) have been applied to study contagion effect between the US stock markets and the Asian stock markets during the Sub-prime crisis period.

The Copula technique dates back to 1959, when Sklar presented his theorem for continuous conditional distributions. During the last decade, the interest of researchers has increased in this area and several researchers have employed copulas to study contagion among various stock and exchange rate markets (Samitas and Tsakalos, 2013; Chen and Fan, 2005; 2006; Syriopoulos and Roumpis, 2009; Meucci, 2010). Recently, researchers have started using Copula models to analyze the dependence structure between any two financial market variables. An asymptotic property of quantile processes under random censoring was examined by Wagener et al., 2012 for stock markets. It was concluded that there existed weak convergence of the quantile process in the region under study, which was linear in nature. Tail dependence between oil and emerging markets was studied by applying copula methodology; left tail dependence was found between oil price and Vietnam financial markets. No significant dependence was found between oil price and Chinese financial markets (Nguyen and Bhatti, 2012). By using time-varying copula and conditional extreme value theory method, tail dependence was studied between the Australian and other international financial markets. Usage of both the methods helped in determining the tail dependence (Wagener et al., 2012). By applying time-varying copula between energy and stock markets; significant increase in dependence between oil and stock
markets was found during the Sub-Prime crisis of 2007-08 (Wen et al., 2012). To model time varying correlation of exchange rates, Patton (2006a) used the concept of conditional copula. Using copula, impact of the US Sub-prime crisis has been studied by Horta et al. (2008) who found that contagion existed for Canada, Japan, Italy, France and UK. Insignificant contagion was found between American stock market and German stock market. Using the conditional extreme value theory and time-varying copula, Nguyen and Bhatti (2012) studied the tail dependence between Australian and other international markets. The findings show that a combination of both the methods helped in inferring the results better. Bucher et al. (2012) suggested the use of bivariate copula from the Archimedean copula to test for contagion. Using Copula technique, Kenourgios et al., (2010) found that during a crisis, the government policy responses are unlikely to prevent the spread of impact of crisis among countries, thereby making domestic risks internationally diversifiable when it is most desirable. Reboredo (2011) found crude oil prices to be linked with the same intensity during bullish and bearish markets. The objective of this chapter is to complement the existing literature by examining the time-varying copula between the US stock market with the Asian markets namely China, India, Indonesia, South Korea, Taiwan, Hong Kong, Malaysia and Japan(in the light of US Sub-prime crisis). To the best of our knowledge, no study has been done in contagion from US equity market to the selected Asian stock markets using time-varying Copula approach.

6.2 METHODOLOGY

Considering two continuous random variables, X and Y, with marginals $F_X(x)$ and $F_Y(y)$ with a joint distribution function $F_{XY}(x,y)$, Sklar’s theorem states that the standard representation for the joint distribution $F_{XY}$ is:

$$F_{XY}(x,y) = C(F_X(x), F_Y(y)),$$  \hspace{1cm} \text{Eq. (6.1)}

Where $C(u, v)$, $u = F_X(x)$ and $v = F_Y(y)$ is the copula that captures the dependence structure between X and Y.

Function $F_{XY}$ in Eq. 6.1 is a joint distribution function with marginals $F_X$ and $F_Y$.

$$F_{XY/w}(x,y/w) = C\left(F_X(x/w), F_Y\left(\frac{y}{w}\right)/W\right),$$  \hspace{1cm} \text{Eq. (6.2)}
Where, $W$ is the conditioning variable, $F_X(x/w)$ is the conditional distribution of $X/W = w$, $F_Y\left(\frac{y}{w}\right)$ is the conditional distribution of $Y/W = w$ and $F_{XY/W}(x, y/w)$ is the joint conditional distribution of $(X, Y)/W = w$.

Under the assumption that all conditional density functions (CDFs) are differentiable, the unconditional and conditional joint density functions are given by:

$$f_{XY}(x, y) = f_X(x).f_Y(y).c(u, v) \quad \text{Eq. (6.3)}$$

$$f_{XY/W}(x, y/w) = \left(f_X(x/w).f_Y\left(\frac{y}{w}\right)\right).c(u, v/w) \quad \text{Eq. (6.4)}$$

Where, $c(u, v) = \frac{\partial^2 C(u, v)}{\partial u \partial v}$ and $c(u, v/w) = \frac{\partial^2 C(u, v/w)}{\partial u \partial v}$ are the conditional and unconditional copula densities, respectively.

Let $R_{\text{stock 1, } t}$ (stock 1 = US) and $R_{\text{stock 2, } t}$ (stock 2 = China, Hong Kong, India, Indonesia, South Korea, Malaysia, Japan, Taiwan) be random variables denoting stock 1 (US) and stock 2 (China, Hong Kong, India, Indonesia, South Korea, Malaysia, Japan, Taiwan) returns at time $t$, and let conditional cumulative distribution functions (CDFs) be $F_{\text{stock 1}}(R_{\text{stock 1, } t}/\psi_{t-1})$ and $F_{\text{stock 2}}(R_{\text{stock 2, } t}/\psi_{t-1})$, where $\psi_{t-1}$ denotes all past returns, $(R_{i, t-j}, i = \text{stock 1, stock 2 and } j = 1, 2, ..., t-1$. The conditional copula function $C_t(u_t, v_t/\psi_{t-1})$, is defined by the time-varying CDF of stock 1 and stock 2 returns, where $u_t = F_{\text{stock 1}}(R_{\text{stock 1, } t}/\psi_{t-1})$ and $v_t = F_{\text{stock 2}}(R_{\text{stock 2, } t}/\psi_{t-1})$ are distributed as continuous uniform variables on (0,1). In extension to the theorem suggested by Sklar, the bivariate conditional CDF of $R_{\text{stock 1, } t}$ and $R_{\text{stock 2, } t}$ can be written as:

$$G(R_{\text{stock 1, } t}, R_{\text{stock 2, } t}/\psi_{t-1}) = C_t(F_{\text{stock 1, } t}(R_{\text{stock 1, } t}/\psi_{t-1}), F_{\text{stock 2, } t}(R_{\text{stock 1, } t}/\psi_{t-1})) \quad \text{Eq. (6.5)}$$

The conditional joint density will be as follows, assuming that all conditional CDFs are differentiable:

$$G(R_{\text{stock 1, } t}, R_{\text{stock 2, } t}/\psi_{t-1}) = \frac{\partial G_t(R_{\text{stock 1, } t}, R_{\text{stock 2, } t}/\psi_{t-1})}{\partial R_{\text{stock 1, } t} \partial R_{\text{stock 2, } t}} \quad \text{Eq. (6.6)}$$
Where \( C_t(u_t, v_t/\psi_{t-1}) \) is a conditional copula density function. Thus, the bivariate conditional density function of \( R_{stock1,t} \) and \( R_{stock2,t} \) given above is represented by the product of the copula density and the two conditional marginal densities \( f_{stock1}(R_{stock1,t}/\psi_{t-1}) \) and \( f_{stock2}(R_{stock2,t}/\psi_{t-1}) \). Then, the log likelihood function is:

\[
\Log g = \log c_t + \log f_{stock1,t} + \log f_{stock2,t}
\]

Eq. (6.7)

For convenience sake, we change the notation of the parameters in \( c_t, f_{stock1,t}, f_{stock2,t} \) as \( \theta_c, \theta_{stock1} \) and \( \theta_{stock2} \). This can further be written as:

\[
L(\theta) = L_c(\theta_c) + L_{stock1}(\theta_{stock1}) + L_{stock2}(\theta_{stock2})
\]

Eq. (6.8)

Where \( L_k \) is the log-likelihood function of copula \( k = c \), stock 1 \( k = \text{stock 1} \) and stock 2 \( k = \text{stock 2} \) densities, respectively.

A two-stage estimation procedure is used while considering multivariate modeling. This is so as it is difficult to achieve a simultaneous maximization of \( L(\theta) \) for all parameters while performing multivariate modeling. To solve this issue, Joe (1997) proposed a procedure known as inference for the margins (IFM). Joe suggested that the IFM method was highly efficient than the usual maximum likelihood method. In order to use the IFM approach in the current paper, we have first extracted the parameters of each univariate model through the maximum likelihood model.

\[
\theta_{stock1} = \arg\max_{\theta_{stock1}} \sum_{t=1}^{T} \ln f_{stock1,t} (z_{stock1,t}/\psi_{t-1}; \theta_{stock1})
\]

Eq. (6.9)

\[
\theta_{stock2} = \arg\max_{\theta_{stock2}} \sum_{t=1}^{T} \ln f_{stock2,t} (z_{stock2,t}/\psi_{t-1}; \theta_{stock2})
\]

Eq. (6.10)

The next step is to apply the marginal CDFs to the standardized residuals. We use the estimates to compute \( \hat{\psi}_t = F_{stock1,t}(Z_{stock1,t}/\psi_{t-1}; \hat{\theta}_{stock1}) \) and
\( \hat{\theta}_t = F_{stock2,t} (Z_{stock2,t} / \psi_{t-1}; \hat{\theta} \text{ stock } 2) \) for \( t = 1 \) to \( T \), and (the second stage) obtain the parameters of the copulas:

\[
\hat{\theta}_c = \arg \max_{\theta_c} \sum_{t=1}^{T} \ln c \left( \hat{u}_t, \hat{v}_t; \theta_c \right)
\]

Eq. (6.11)

The normal and the Student-t density function can further be extended to the skewed-t density function. A normal distribution has an implied kurtosis and skewness of 3 and 0, respectively. Fat tails and asymmetry are the two most important deviations from normality conditions (Bastianin, 2009). A skewed-t density function is an improvement over Student-t density function as the latter captures only excess kurtosis whereas the former can capture both skewness and kurtosis.

\[
\text{Skewed-t } (z/\eta, \phi) = \left[ bc \left( 1 + \frac{1}{n-2} \left( \frac{bz+a}{1-\phi} \right)^2 \right)^{\eta+1/2} \right], z < \frac{a}{b}
\]

Eq. (6.12)

\[
= \left[ bc \left( 1 + \frac{1}{n-2} \left( \frac{bz+a}{1-\phi} \right)^2 \right)^{\eta+1/2} \right], z \geq -\frac{a}{b}
\]

The values of \( a, b \) and \( c \) are defined as:

\[
a \equiv 4\phi c \, \frac{\eta-2}{\eta-1}, \quad b \equiv 1 + 3\phi^2 - a^2, \quad c \equiv \frac{\Gamma(\eta+1/2)}{\sqrt{\pi} \, (\eta-2)} \times \frac{1}{\Gamma(\eta/2)}
\]

Eq. (6.13)

where \( \eta \) is the parameter for kurtosis (kurtosis being measure of the peakedness as well as fat tailedness of the distribution) and \( \phi \) is the asymmetry parameter. The restrictions for \( \eta \) and \( \phi \) are: \( 2 < \eta < \infty \) and \( -1 < \phi < 1 \). When \( \phi = 0 \), then the normal distribution is obtained, while the Student-t distribution for \( \phi = 0 \) and for \( \eta \to \infty \). Like the Student-t distribution, it is well defined only for \( \eta > 2 \), the skewness exists only for \( \eta > 3 \), and the kurtosis exists only if \( \eta > 4 \). The mode of density is to the left of zero and the variable is skewed to the right, in case \( \phi > 0 \); vice-versa for \( \phi < 0 \).

Patton (2006a) has suggested that the K-S test (Kolmogorov-Smirnov) test should be performed in order to test the empirical adequacy of the marginal models. This test has been suggested as modeling copulas would require model for marginal distributions to be distinguishable from the true ones. The probability integral transforms will be non-uniform (0, 1) if a mis-specified model is used for the
marginal distributions. If a mis-specified model is used, any copula model will automatically be mis-specified.

A Gaussian copula and a Student-t copula are usually the best choice of an elliptical copula, which is used for the dependence structure. They are defined by:

\[
C_t^{\text{Gaussian}}(u_t, v_t; \rho_t) = \Phi(\Phi^{-1}(u_t)\Phi^{-1}(v_t)), \quad \text{Eq. (6.14)}
\]

\[
C_t^{\text{Student-}t}(u_t, v_t; \rho_t, v_c) = T(t^{-1}_v(\Phi^{-1}(u_t), t^{-1}_v(\Phi^{-1}(v_t))), \quad \text{Eq. (6.15)}
\]

In the Gaussian copula, \( \Phi \) is the bivariate standard normal CDF with correlation \( \rho_t \) \((-1 < \rho_t < 1)\) between \( R_{stock1,t} \) (stock1 = US stock markets) and \( R_{stock2,t} \) (stock2 = China, Hong Kong, India, Indonesia, South Korea, Malaysia, Japan, Taiwan). \( \Phi^{-1}(u_t) \) and \( \Phi^{-1}(v_t) \) are standard normal quantile functions.

In the Student-\( t \) copula, \( T \) is the bivariate Student-\( t \) CDF with a degree of freedom parameter \( v_c \) and correlation \( \rho_t \) \((-1 < \rho_t < 1)\). The quantile functions of the univariate Student-\( t \) distribution with \( v_c \) as the degree of freedom parameter are \( t^{-1}_v(u_t) \) and \( t^{-1}_v(v_t) \).

When the weight of the joint density in one or both tails is larger than that of a multivariate normal density, it is referred as tail dependency. In a multivariate set up, the fat tail phenomenon is known as tail dependency. Suppose, an event in \( X \) occurs whose probability is less than \( v \). Also, an event has occurred with probability lower than \( Y \), the formula for tail dependence will be as follows:

\[
\lambda_L(v) = \lim_{v \to 0} P \left[ X \leq F^{-1}_X(v) \right] = \lim_{v \to 0} \frac{C(v,v)}{v}, \quad \text{Eq. (6.16)}
\]

\[
\lambda_U(v) = \lim_{v \to 1} P \left[ X \geq F^{-1}_X(v) \right] = \lim_{v \to 1} \frac{1 - 2v + C(v,v)}{1 - v}, \quad \text{Eq. (6.17)}
\]

Where \( C(\cdot, \cdot) \) is the CDF of the copula and \( F_X(\cdot) \) and \( F_Y(\cdot) \) are the marginal CDFs for \( X \) and \( Y \), respectively. Symmetric tail dependencies are presented by Gaussian and Student-t copulas which are given by \( \lambda^{\text{Gaussian}}_L = \lambda^{\text{Gaussian}}_U = 0 \) and \( \lambda^{\text{Student-}t}_L = \lambda^{\text{Student-}t}_U = \sqrt{2v+1}\sqrt{1-\rho/\sqrt{1+\rho}} > 0 \), where \( t_{v+1}(\cdot) \) is the CDF of the Student-\( t \) distribution with the degree of freedom \( v+1 \) and \( \rho \) is the linear correlation coefficient between \( X \) and \( Y \), respectively.
The symmetrized Joe-Clayton (SJC) copula considers the lower and the upper tail dependence whereas the Clayton copula considers only the lower tail dependence. The SJC copula’s dependence measures completely determining the presence or absence of symmetry.

The formula is as follows:

\[ C_{t}^{SJC} = (u_t, v_t, \lambda_U^{SJC}, \lambda_L^{SJC}) \]

\[ = 0.5 \left( C_t^{JC}(u_t, v_t, \lambda_U^{JC}, \lambda_L^{JC}) + C_t^{JC}(1-u_t, 1-v_t, \lambda_U^{JC}, \lambda_L^{JC}) + u_t + v_t - 1 \right). \quad \text{Eq. (6.18)} \]

where \( C_t^{JC}(u_t, v_t, \lambda_U^{JC}, \lambda_L^{JC}) = 1 - \left( 1 - \left( 1 - (1-u^\tau)^k \right)^\gamma + \left( 1 - \left( 1 - v^\tau \right)^k \right)^\gamma - 1 \right)^{-1/k} \).

In this copula function, the tail dependence coefficients are themselves the parameters of the copula function. If \( \lambda_U^{SJC} = \lambda_L^{SJC} \) condition is fulfilled, the market structure is symmetric; otherwise it is asymmetric.

In this paper, we have considered Kendall’s \( \tau \) as the main measure of association, since contagion is considered to be a non-linear phenomenon (Rodriguez, 2007). The linear correlations cannot capture the non-linear dependencies that Kendall’s \( \tau \) can capture. The SJC copula has upper and lower Kendall’s \( \tau \) in its CDF \( \lambda_U^{SJC}(v) = \tau_U \) and \( \lambda_L^{SJC}(v) = \tau_L \). While the Gaussian copula and the Student-t copula only has the linear dependence parameter \( \rho \) in their CDFs. Therefore, for the Gaussian and the Student-t copula, a relation needs to be developed between the linear dependence parameter \( \rho \) and the non-linear dependence parameter \( \tau \). The relationship is defined as follows:

\[ \tau = \left( \frac{2}{\pi} \right) \sin^{-1}(\rho). \]

Equations (6.15) and (6.16), respectively define the evolution of upper and lower Kendall’s \( \tau \) for the SJC copula (Patton, 2006 a).
Data employed in this study are log returns of daily closing stock market indices for the US, Asian stock markets, namely, China, Hong Kong, Indonesia, South Korea, Malaysia, Japan, India and Taiwan. The various indices that have been considered are mentioned in Table 4.1 in Chapter 4. The period of 8 years from January 2004 to December 2011 (1486 observations for each country) has been studied. The data have been compiled from BLOOMBERG. To avoid spurious results, those observations where data were unavailable, because of holidays or other reasons, for at least one market have been eliminated.

6.3 EMPIRICAL RESULTS

6.3.1 Maximum Likelihood Estimates of Copula

Table 6.1 reports the maximum likelihood parameter estimates of the Gaussian copula and the SJC copula functions for the US and the Asian economy pairs. Table 6.1 also reports the results of the time varying Copula functions. It can be seen that the dependence parameters for the given Asian countries are substantial and positive for all the pairs of stock markets and thus, support the evidence of integration, contagion and dependence from US to the selected Asian stock markets. This also indicates that wherever the value of dependence parameter is high, those countries from the Asian group are like to commove with the changes in the US markets. Moreover, the value of the dependence parameter is positive for all the cases indicating that the increase in index value of the US market will coincide with the appreciation in index values from the Asian economies.

The Gaussian copula for US-China pair shows that the co-efficient value in all the paired markets is very close to zero implying low level of persistence implying that any shock to one market can drift the correlation between markets, away from the long run-equilibrium value/ position for a very short period of time. Following Hsu et al. (2008), if the co-efficient value is close to 1, the correlation between the two stock
markets is highly persistent. High persistence would mean that if a market is hit by a crisis, then the correlations between the markets will get pushed away from its long run average for a significant period of time. While correlations have a tendency of reverting back to its mean position; a low persistence level would lead to very little push in correlations away from long-run equilibrium level. If the series demonstrates non-linear behavior in the joint and marginal distributions of assets, it may show high level of persistence in correlations (Lima, 1998). For all the other pairs of markets except US-China, the co-efficient value with Gaussian copula is between 0.2 and 0.3 which is relatively higher than US-China estimate. The persistence level indicates that any shock to US stock markets will push the correlation between markets away from the long-run average value for a shorter period of time but not as short as US-China.

The log likelihood values, AIC and BIC of Gaussian copula and SJC (Symmetrized Joe-Clayton) copula for all pairs of markets have been compared. The three measures (Log-likelihood, AIC and BIC) suggest that SJC copula is a better method to measure contagion than the normal copula for all the pairs of stock markets under study. Thus, the SJC copula is a better measure than the Gaussian copula as it is able to capture lower as well as upper tail dependencies between the pairs of countries. Therefore, Gaussian copula with no-tail dependence may not be considered to be an optimal measure of contagion.

In all the pairs of markets, the β (Beta) estimate is significant which implies that the dependence is time-varying. Since, the dependence between the markets is changing with time, a constant correlation model or a constant copula model would not be an appropriate model for defining dependence between markets. Thus, time varying Gaussian and SJC copula has been worked out as constant copula may not be adequate in describing the dependence structure between markets. The β (Beta) values of time varying SJC copula indicates that if there is an increase in the stock prices of one country, then what would be the effect on stock prices of other countries. The upper tail values of time-varying SJC copula for all the pairs of markets under study are positive with an exception of US-China pair which is negative. Positive upper tail values suggest that if the stock prices would increase in US market, then correspondingly they would increase in other Asian markets for which upper tail values are positive. If the upper tail values of SJC copula are negative, as in case of
US-China pair, it would suggest that a decrease in stock price in US market would lead to decrease in stock prices in Chinese stock market. On examining the time-varying Gaussian and SJC copula, the Log-likelihood, AIC and BIC values all show that the time-varying SJC copula is a comparatively superior measure than time-varying Gaussian copula for all the pairs of stock markets as for all the pairs of markets, log-likelihood values are higher for time varying SJC copula than for time-varying Gaussian copula. Further, this result is validated by higher AIC and BIC values for time-varying SJC copula than time varying Gaussian copula for all the pairs of markets.

On observing the time-varying Gaussian copula coefficients, following things were examined. The degree of persistence is measured by $\beta$ (Beta) whereas $\gamma$ (Gamma) represents the adjustment that is made in the dependence process. The negative values of $\gamma$ (Gamma) indicate significant variations over time in the dependencies between all the pairs of stock markets. The maximum variability in the dependence level is for two pairs, i.e. US-Japan and US-Malaysia as modulus values of $\gamma$ (Gamma) are highest for these two pairs. Indian and the South Korean stock markets have greater dependencies with the US stock market as the $\Omega$ (Omega) values are higher for these pairs of countries than the rest of the market pairs. With time-varying SJC copula values, the negative values of $\gamma$ (Gamma) are observed for four pairs, i.e. US-Hong Kong, US-Malaysia, US-Taiwan and US-China suggesting that there is significant variation over time in the dependencies between the four pairs of stock markets.

If we look at the results for normal copula of USA and India (Figure 6.1), we can see that the time varying dependence structure changes significantly during the period of sub-prime crisis (as evidenced in the sudden change in time varying correlation graph between observation 500 and 1000). During the pre-crisis period (time varying correlation graph between observation 0 and 500), the dependence structure is less volatile and also during the post-crisis period (time varying correlation graph between observation 1000 and 1500). We can infer similar results from the plots for all the pairs of countries. For all the pairs of countries, we can see that the dependence structure between the US stock market and the respective market took a sharp plunge between the observation 500 and 1000. By carefully looking at the normal copula plots of the pair of US-Hong Kong, one can infer that the during the pre-crisis period,
the dependence structure was not so much volatile and it continued similarly, during post crisis period. During the crisis period, the time-varying dependence structure fell drastically showing the response of Hong Kong stock markets on the US housing bubble of 2007-08. Similar results can be inferred for US-Japan pair and US-South Korea pair. US-Taiwan pair depicts very high volatility in the time varying dependence structure during the crisis period which continues during the post-crisis period too. For US-Malaysia pair, the time-varying dependence structure during the crisis period and post crisis period is highly volatile whereas for US-Indonesia pair, high volatility can be seen only during the crisis period. For USA and China pair, the fall in the dependence structure might not look so drastic as in other cases. This however, does not mean that the Chinese markets were not affected by the 2008 crisis. While interpreting the results one need to see that there is change in the time varying dependence structure, which need not be too drastic or too much. The change in the dependence structure is calculated on the basis of one previous value implying that if there is a change in the time-varying dependence structure as compared to previous value, then there exists contagion. This is further validated by the results of Table 6.1.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gaussian Copula</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$ (Beta)</td>
<td>0.278</td>
<td>0.271</td>
<td>0.215</td>
<td>0.209</td>
<td>0.282</td>
<td>0.197</td>
<td>0.213</td>
<td>0.088</td>
</tr>
<tr>
<td>LL</td>
<td>-59.795</td>
<td>-56.918</td>
<td>-35.367</td>
<td>-33.197</td>
<td>-61.501</td>
<td>-29.461</td>
<td>-34.538</td>
<td>-5.777</td>
</tr>
<tr>
<td><strong>SJC Copula</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tou(u)</td>
<td>0.134</td>
<td>0.166</td>
<td>0.128</td>
<td>0.100</td>
<td>0.192</td>
<td>0.107</td>
<td>0.105</td>
<td>0.003</td>
</tr>
<tr>
<td>Tou(L)</td>
<td>0.140</td>
<td>0.135</td>
<td>0.059</td>
<td>0.083</td>
<td>0.110</td>
<td>0.055</td>
<td>0.080</td>
<td>0.020</td>
</tr>
<tr>
<td><strong>Time Varying Gaussian Copula</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Omega$ (Omega)</td>
<td>1.122</td>
<td>0.446</td>
<td>0.355</td>
<td>0.419</td>
<td>1.016</td>
<td>0.805</td>
<td>0.294</td>
<td>0.321</td>
</tr>
<tr>
<td>$\gamma$ (Gamma)</td>
<td>-0.188</td>
<td>-0.124</td>
<td>-0.137</td>
<td>-0.327</td>
<td>-0.235</td>
<td>-0.390</td>
<td>-0.170</td>
<td>-0.181</td>
</tr>
<tr>
<td>$\beta$ (Beta)</td>
<td>-1.539</td>
<td>0.734</td>
<td>0.719</td>
<td>0.728</td>
<td>-0.998</td>
<td>-1.240</td>
<td>1.008</td>
<td>-1.408</td>
</tr>
<tr>
<td>LL</td>
<td>-61.703</td>
<td>-61.581</td>
<td>-38.964</td>
<td>-46.401</td>
<td>-65.022</td>
<td>-33.921</td>
<td>-40.244</td>
<td>-6.582</td>
</tr>
<tr>
<td>BIC</td>
<td>-123.391</td>
<td>-123.146</td>
<td>-77.913</td>
<td>-92.787</td>
<td>-130.030</td>
<td>-67.828</td>
<td>-80.473</td>
<td>-13.149</td>
</tr>
<tr>
<td><strong>Time Varying SJC Copula</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper tail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Omega$ (Omega)</td>
<td>-1.457</td>
<td>-5.310</td>
<td>-3.384</td>
<td>-0.692</td>
<td>-1.543</td>
<td>-2.721</td>
<td>-1.992</td>
<td>-8.079</td>
</tr>
<tr>
<td>$\gamma$ (Gamma)</td>
<td>-3.209</td>
<td>7.905</td>
<td>2.473</td>
<td>-5.189</td>
<td>-2.221</td>
<td>-0.583</td>
<td>-1.958</td>
<td>-1.944</td>
</tr>
<tr>
<td>$\beta$ (Beta)</td>
<td>3.870</td>
<td>3.707</td>
<td>4.411</td>
<td>2.851</td>
<td>3.802</td>
<td>7.320</td>
<td>5.007</td>
<td>-0.009</td>
</tr>
<tr>
<td>Lower tail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Omega$ (Omega)</td>
<td>-1.861</td>
<td>1.138</td>
<td>-4.280</td>
<td>-10.421</td>
<td>-3.466</td>
<td>-1.572</td>
<td>1.093</td>
<td>2.343</td>
</tr>
<tr>
<td>$\gamma$ (Gamma)</td>
<td>0.158</td>
<td>-10.286</td>
<td>3.516</td>
<td>18.195</td>
<td>3.923</td>
<td>-4.316</td>
<td>-8.042</td>
<td>-17.767</td>
</tr>
<tr>
<td>$\beta$ (Beta)</td>
<td>-0.297</td>
<td>-0.087</td>
<td>5.462</td>
<td>1.210</td>
<td>-0.190</td>
<td>2.942</td>
<td>-11.067</td>
<td>-3.794</td>
</tr>
</tbody>
</table>

Source: Author’s calculations
Figure 6.1: Normal Copula for all pairs of Countries
(US viz-a-viz Asian Countries)\(^{36}\)

The numbers on the x-axis represents the dates, where, 1 represents “01-01-2004” and 1500 represents “19-12-2011”. The number is used by the software as the plots are the output of the analysis.
Figure 6.2: (Symmetrized Joe-Clayton) SJC Copula for all pairs of countries,
(US viz-a-viz Asian Countries)\(^{37}\)

The numbers on the x-axis represents the dates, where, 1 represents "01-01-2004" and 1500 represents “19-12-2011”. The number is used by the software as the plots are the output of the analysis. Y axis represents constant and time-varying SJC copula.

\(^{37}\) The numbers on the x-axis represents the dates, where, 1 represents "01-01-2004" and 1500 represents “19-12-2011”. The number is used by the software as the plots are the output of the analysis. Y axis represents constant and time-varying SJC copula.
When a market crashes or during periods of high volatility, the financial returns of that country do get impacted. To assess the joint extreme events during such periods of turmoil, tail dependencies prove to be useful. Figure 6.2 demonstrates lower and upper tail dependencies from SJC copulas; the blue line depicts the time varying dependence structure whereas the red line shows the constant dependence structure between the two stock markets under study. The literature suggests that in case of equity returns, joint negative extremes are reflected more than joint positive extremes. This leads one to assume that upper tail dependencies are less strong than lower tail dependencies. From Table 6.1, we can see that $\Omega_{\text{L}}^{\text{SJC}}$ (Omega of SJC copula of lower tail dependence) is higher than $\Omega_{\text{U}}^{\text{SJC}}$ (Omega of SJC copula of upper tail dependence) for most of the cases. This further implies that the lower tail dependence is higher than upper tail dependence.

These results indicate that the extent of impact of downfall during the period of sub-prime crisis was not that much for India as it was for other economies under study. Since, the copula is a better measure than DCC and ADCC GARCH methodology; it is able to demonstrate that the Indian stock market did not get impacted immediately due to US Sub-prime crisis as the copula methodology takes into account the linear as well as non-linear dependence between two series.

On the other hand, for US-China, the lower tail dependence is much stronger than the upper tail dependence as depicted by the US-China SJC Copula plot. The upper tail plot shows that the time-varying dependence structure does not vary much. This indicates that when market is trending down, the risk management and diversification strategies becomes less effective if there is stronger lower tail dependence. Hence, the focus of risk managers should be on the lower tail during such periods while designing portfolio re-balancing and risk management strategies. This can help the risk managers and regulators to avoid condition of joint crash.

The impact of global financial crisis has led to sudden changes in the dependence structure between USA and Indonesia stock markets. The lower tail shows that there has been volatility throughout the period whereas the upper tail shows that there has been very less or rather negligible volatility during the period under study.
The similar inference can be obtained for the lower tail and upper tail estimates based on the SJC copula plots. This indicates that there is sudden change in dependence structure between USA and Japan stock markets due to the impact of global financial crisis. The lower tail remains constant during the pre-crisis period. During the crisis period, the dependence structure reacts towards the US-Subprime crisis. For US Indonesia SJC copula plot pair, one can observe that the time-varying dependence structure does not vary much. It is nearing the constant red line depicted in the plot. This shows that there is not much volatility in the dependence structure between US-Indonesia pair. Similar results can be inferred for US-Malaysia pair. The US-Taiwan’s SJC copula lower tail shows too much of volatility in the time-varying dependence structure between the two country’s stock market prices which shows that the Taiwan stock market did get impacted due to the financial crisis of 2007-08 which started in the US. For US-South Korea pair, the lower tail dependence structure is less volatile than the upper tail.

6.5 CONCLUDING OBSERVATIONS

Most of the countries under study have shown changes in the macro-economic fundamentals in the recent past. The volatility in the financial markets and uncertainty among the global investors during a crisis further impacts the stock markets of a country even if the fundamentals of the country does not show any change. Moreover, policy makers seek to study the existence of contagion among markets so that they can strategically manage risk and this further helps in asset allocation. If the markets are contagious, then the investors will be unable to reap benefits through international diversification of portfolio. In such a case, the policy makers will further frame policies so that they can insulate themselves from inflicting heavy damage from various crises. The methodology used in the paper showed that most of the countries have been affected due to the financial crisis of 2007-08 which started in the US but finally spread to other parts of the world. This would help the policy makers to understand the dependence structure among the countries and frame policies accordingly.

The present study has made an attempt to examine contagion from US stock market to Asian markets and has found that the Asian markets have got affected because of the US Sub-prime crisis 2007-08. Asian economies might have got affected due to the
ripple effect of the crisis. This means that when US financial markets were facing liquidity crunch, the FIIs pulled out the money invested in other parts of the world in order to fulfill the liquidity requirements in the US. The bulk selling of shares in Asian markets by FIIs led to panic situation and many uninformed investors would have also sold their holdings without much understanding the situation. This led to fall in share prices and continuous fall would lead to depressive sentiments of investors thus further deteriorating the condition in the stock market.

The copula methodology has enabled us to examine contagion from US stock markets to few selected Asian stock markets including India. As discussed earlier, the advantage of copula over other methodologies is that it examines the contagion when the series are non-linear in nature also. The copula methodology has pointed out that the Asian markets have contagion effect due to Sub-prime crisis whose epicenter is the US. The copula methodology also focuses on the tail dependence structure of the series. The results indicate that for few countries, the impact of global financial crisis has led to sudden changes in the dependence structure between USA and the respective stock markets. For others, like USA-China pair, the lower tail dependence is much stronger than the upper tail dependence indicating that the government might have come up with lot of policy measures to be able to withstand any crisis that would occur in future. However, lower tail dependence being stronger than upper tail shows that in event of trending down market, the risk and diversification strategies become less effective; i.e. the policy measures that the government had taken before such crisis situation did not prove to be effective during tranquil times. The other extreme case is that of India-USA pair where upper tail dependence is much stronger than the lower tail dependence which shows that the Indian stock market reacted quite late to the housing bubble that took place in the US in 2007-08. Thus, the results clearly show that the Asian stock markets had impact of the US Sub-prime crisis.
CHAPTER 7: CONCLUSION AND POLICY IMPLICATIONS

The present study has made an attempt to examine the co-integration of Indian stock market with other selected Asian stock markets. The study serves as a catalyst to examine possibility of existence of financial contagion between the US stock market and few selected Asian stock markets which have the maximum presence in terms of capital inflow through FIIs and in the map of market capitalization. The study is particularly conducted in order to study the impact of the US Sub-prime crisis 2007-08 on the selected Asian countries. The study also uses novel approach by applying methods which can be applied in linear and non-linear data series. The study empirically investigates the relationship between stock markets during tranquil times and during periods of turmoil to examine if there is any change in the correlations between them. Further, the study has been done in the light of institutional reforms initiated in the Indian financial system post 1991. As discussed in chapter 2, the year 1991 holds significance in the history of economic and financial scenario of India as lot of reforms were initiated during this period. Thus, this study contributes to the existing literature on co-integration and financial contagion between markets in the light of reforms instigated in the financial sector. The period of study has also been taken from 1991 as this year was the turning point in the history of Indian financial markets. The study also incorporates endogenously determined structural breaks which help us in building the conclusion and suggest policy implications.

Chapter 2 brings out the evolution of the Indian capital market, with special orientation to the reforms initiated in the financial system during the nineties. The reforms were instigated with an aim of enhancing transparency, improving market efficiency, reducing risk in transactions, preventing unfair trade practices and increasing risk containment measures to bring the Indian capital market to international standards and to increase the capital inflow towards India. As seen in figure 2.1, in Chapter 2, we find that capital inflow by way of FIIs has increased from Rs 13.4 crores in the year 1993 to Rs 133266.80 crores in the year 2010. Post the reforms in the financial sector, the Indian financial market is compared with other developed countries of Asia and the world. The reforms have liberated the markets and made them transparent to encourage more participation in the system.
A brief survey of the existing literature is made in Chapter 3 of this study. The survey of literature expresses the viewpoints of many researchers on the meaning of contagion and difference between contagion and interdependence. The survey covers the debates—both theoretical and empirical—on contagion and various methodologies of measuring contagion. The study helps us in finding out the gaps in the literature to justify the present study in its current form. The literature review brings out the advantages and limitations of various methods of measuring contagion which guides us in deciding which methodologies to apply in our study, thus incorporating the developments in the recent time-series studies. A comprehensive exploration of the various causes of contagion has also been examined.

Chapter 4 deals with examining co-integration between the Indian stock market with other selected Asian stock markets. If the markets are interdependent, then the next step would be test for contagion from one market to the other. The methodology adopted to test for co-integration was Gregory and Hansen (1996) because as suggested by Herzer and Felicitas (2006), standard co-integration tests tend to falsely accept the null of no co-integration when there is a structural break under the alternative hypothesis. Thus, this study attempts to apply the Gregory and Hansen (1996) co-integration technique that allows for one endogenously determined structural break in the co-integration relationship. Thus the linkages between Indian and other Asian stock markets has been explored using robust time-series analytical tools that endogenize structural breaks in the stock return series and their relationship. The findings of the study brings out that the Indian stock market are co-integrated with all the Asian markets under study, though the level of integration is less for most of the countries.

Chapter 5 tests for contagion from the US stock market to all the selected Asian stock markets. The chapter brings out the analytical framework of the contagion during the Sub-prime crisis of 2007-08 and its impact on the Asian stock markets. The methodology used for examining contagion is DCC-GARCH and ADCC-GARCH model by dividing the data into pre-crisis, during crisis and post crisis period. Apart from capturing the time-varying correlation done by DCC-GARCH, the ADCC-GARCH model also captures the leverage effect. The leverage effect allows a researcher to examine the impact of positive news and negative shocks in one country.
on the stock markets of other countries. The findings of the study show that the housing bubble of 2007-08 in the US affected nearly all the Asian markets under study.

Chapter 6 investigates for contagion from the US stock market to all the Asian stock markets under study using Copula method. The copula method is used by researchers to analyze the dependence structure between any two financial market variables. By applying time-varying copula between the shock struck US stock market and the Asian stock markets, significant increase in dependence between the stock markets was found during the Sub-Prime crisis of 2007-08. Through SJC Copula, observations regarding lower and upper tail dependence were made. If the lower tail dependence is much stronger than the upper tail dependence, it indicates that when the market shows a downward trend, the risk containment measures and the diversification strategies become less effective; as strongly depicted in the case of US-China pair. On the other hand, if the upper tail dependence is stronger than the lower tail dependence, it depicts that the impact of downfall/crisis is much less for the particular pair of countries; as has been seen for US-India pair. Thus, these inferences help the portfolio managers in designing risk management strategies.

7.1 POLICY IMPLICATIONS

The issues of interdependence of financial markets have always interested financial economists and investment advisors (Bartram et al., 2007). In recent times, the area of interdependence and contagion has gained importance due to its implications on the asset allocation and portfolio diversification. Mixed results provided by the literature on contagion in equity markets urged to focus the study on examination of contagion from the US to Asian markets during the Sub-prime crisis period. Before studying contagion, importance is laid to study the interdependence between markets so that we can further examine contagion and understand market behavior. There is lot of work done in the area but the market situations keep on changing and hence, there was a need to revisit the work. Further, the dynamics of the financial markets, economic structure and policies have changed dramatically that it was necessary to understand the impact of one market on the other.
Improvement in technology can be blamed for market integration as due to which information sharing has become very easy. From open outcry system of trading to SBTS (Screen Based Trading System), all has become possible due to technological improvements. Through online trading, placing orders have become very easy. From physical copy of contract notes to e-contract notes, account statement summary and balance of securities in the dematerialization account with a click of a button has become real and is no more a fairy tale. System trading has further reduced the need to manually put orders in the trading system. The orders are put automatically if the system finds a gap in the price of a security in different markets. In arbitraging, the trader earns the returns by playing on market inefficiency. Thus, in the light of current technological developments and initiation of reforms in the financial sector, there was a need to examine co-integration between markets.

The study would help traders as they need to hedge their portfolios against unforeseen risks. Thus, a portfolio manager and international investors would diversify their portfolios by investing in different countries. Different countries not only means different in terms of geographical boundaries, but also different in terms of reacting differently to an external shock to the financial markets. Countries which are less affected by the shocks in other parts of the world would be preferred destination for the investors. The foreign investors can use the co-movement relationship between the markets and exchange rates while investing in the foreign markets. The above study would also help the policy makers in framing policies.

The policy makers would prefer that the financial markets of the country should not react to each negative or positive information shocks pertaining to other parts of the world. They would want to negate the impact of such shocks in the country and hence would frame such policies so that they are able to insulate themselves against such shocks. This would make the country more stable, financially and economically. It would further attract more capital inflows into the country.

For banks and financial institutions, the study is all the more important as they serve as intermediary to many international investors and agencies. Sometimes, they also act as insurance agents to international investors to reduce burden of possible risk. Thus, if the bankers are aware of the contagion effect between various pairs of countries they will be able to take informed decisions.
The findings have implications towards portfolio managers because of their interest in knowing the conditional correlations between foreign and domestic markets so as to extend the portfolio with assets from the foreign markets. The high correlation between the markets during the periods of crashes and crisis can help them to diversify the portfolio by including assets from foreign markets and take appropriate positions in a market so as to earn substantial economic gains in returns. This can help investors in designing investment strategies to deal with undesirable movements in markets and to earn substantial gains in returns.

For regulators, they can use the information of contagion in designing the policies that will try to maintain stability in the market. Instability in the market adversely impacts the economic and financial condition of the market. This can also help the policy makers in avoiding the catastrophic impact of recession in developed markets on domestic economy.

For central banks and government: impact on financial markets due to spillover effect of crisis in other parts of the world would help the central bank in deciding the level of interest rates in the economy. It would help them in designing the monetary policy of the economy and further decide whether to curb or boost public expenditure by changing the levels of interest rates prevalent in the financial system.

7.2 THE EPILOGUE

The study demonstrates the financial system in the pre-reform era, i.e. prior to year 1991 which spelled out lot of policy changes in the financial and economic sector of India. India was lagging behind in policy reforms which were acting as a hurdle for foreign as well as domestic investors to invest in India. Lack of transparency, risk containment measures, capital adequacy norms, screen based trading, lack of a watchdog, demutualized exchanges etc; made it difficult for Indian stock markets to attract domestic and foreign capital inflows. Thus, the post 1991 era witnessed the above mentioned much needed reforms like setting up of SEBI Act 1992, setting up of investor protection funds, rolling settlement of trades, risk management measures, increase in the number of stock exchanges leading to increase in investor base, trading volumes, members to stock exchanges, increase in market capitalization, number of listed stocks etc. The technological improvements have generated informational
efficiency and easy access to information which has led to integration of financial markets. Thus, the focus of the researchers has shifted to examine whether financial markets are inter-linked or interdependent on each other or not. This is because of majorly two reasons: one, because of globalization the international investors are able to invest in different global markets, thus increasing the opportunity set. Two, increased access to information has led economies to reduce barriers between them, leading to possibility of integration of economies. Integration of financial markets of two or more countries has its own pros and cons: on one hand, it will limit the benefits of international diversification of portfolio as crisis is one country might affect the financial health of the others; on the other hand, if the markets are not integrated then, the traders, bankers, regulators, policy makers can frame policies keeping in mind the macro-economic fundamentals of the specific country only, than the whole economic universe. If the stock markets are integrated, then the next step would be to examine contagion between markets in case a country undergoes times of turmoil. The crisis might be due to political instability, economic upheavals, financial crisis, terrorist attacks etc. If there exists contagion between markets, then the non-crisis originating countries might get affected due to spillover effect of negative news in some part of the world.

Further, in the current scenario, there exists need to examine contagion even though some work has been done in this regard as the degree of integration between the countries would change over a period of time, as the economic, financial and political conditions of an economy and the world keeps on changing (Huyghebaert and Wang, 2010; Morana and Beltratti, 2008). This gives rise to continuously monitor the level of interdependence and contagion to aid the portfolio managers in designing investment policies for their client investors. Since the impact of any crisis on developing countries is likely to face dilemmas which in turn depends on many factors such as the policies that the country follows during quiet times; such as liberal or stringent macro-economic policies, buffers that the country carries for possible shocks/ crisis, initiation of public expenditure, fiscal and monetary deficit, creating a regulated business environment or deregulated healthy business competitive environment etc. Whether a country will be able to effectively respond to the crisis or not would depend upon the ability of the developing country to change or increase domestic demand to counter act slowing international demand in order to put the
country back into the same situation as before the crisis or at least; minimally get affected by the crisis. For changing the domestic demand, the economists will have to work around the fiscal position of the country, the level of debt that the country is carrying, the level of development of the banking sector and the financial markets and much more (Lin, 2008). Thus, if a country wants to take policy measures to insulate itself from possible losses due to crisis in some other parts of the world; then it would require lot of structural changes in the economy. It has been observed that the level of integration among the economies is growing due to many factors already spelt like trade linkages, level of education of investors and their behavior, level of political stability, volatility spillover and many more. Thus, it becomes even more important and at the same time difficult for a country to shield itself from shocks in other parts of the world.

Recent studies have pointed out that the global financial crisis of 2007-08 has strongest impact on Asian stock markets due to the shift in the risk appetite of investors (Chudik and Fratzscher, 2011; Wang, 2014). It is further suggested that prior to the sub-prime crisis, most of the crisis propagated due to excessive linkages between the countries (Dewandaru et al. (2015). It was also found that over the years, investors’ behavior and sentiments have changed; especially during tough times. If the investors have lost confidence in the system and follow herd behavior, the economy would witness capital outflow and would become more prone to fragility during tranquil times. To reduce vulnerability to exogenous shocks during tranquil times; the government can frame short term stabilization policies such as to increase the credit cost as a pro-active monetary policy measure; to achieve sustenance of foreign exchange; diversify trade linkages across various sectors and different regions; revisit regional market and trade integration etc.

To sum up, the present study hopes to encourage further research in the area of co-integration and contagion between stock markets. The study considers eight Asian countries which contribute the maximum market capitalization and foreign capital inflow among all the Asian countries. The study examines co-integration of Indian stock market with other Asian stock markets in the light of institutional reforms undertaken in India post 1991. The improved market efficiency, globalization, entry of foreign investment/ capital in India by way of FII, improved information
technology created an urge to examine the contagion between stock markets. The study incorporates the possible existence of structural breaks which have been endogenously determined by applying Lee and Strazicich (2003, 2004). This study also applies Gregory and Hansen (1996) co-integration technique that allows for one endogenously determined structural break in the co-integration relationship. An extension to the study could be to endogenously determine structural breaks while examining contagion between stock markets. A modest attempt made in this study was to examine contagion when the series are non-linear in nature. It is expected that the attempt made in this study to examine contagion will serve as a base to conduct further research in this area as over a period of time, further reforms in the area of financial sector and technological improvements would take place. The implications of the study would go a long way in studying the co-integration of the Indian stock market with its peers. The study can further be extended for different types of shocks, namely, political unrest, terrorist attacks, economic crisis etc. In the light of the ongoing European crisis and possibility of China going into depression can also be examined. The trend of occurrence of crisis and its impact can be examined for further research in this area.