

Contagion Effect of Global Financial Crisis on Stock Market in India

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Abstract

This study examines whether contagion effects exist on Indian stock market, during the current financial crisis originated from the US. Following Forbes and Rigobon (2002) we define contagion as a positive shift in the degree of co-movement between asset returns. We use stock returns in BSE and NASDAQ as representatives of Indian and US markets respectively. To measure the degree of co-movement time-varying correlation coefficients are estimated by the dynamic conditional correlation (DCC) multivariate GARCH model of Engle (2002). In order to recognize the contagion effect, we test whether the mean of the DCC coefficients in crisis period differs from that in the pre-crisis stable period. The identification of break point due to the crisis is made by Bai-Perron (1998, 2003) Structural break test. Empirical findings show that there has been a significant increase in the mean of correlation coefficient between the markets in the crisis periods compared to the pre-crisis period. This proves the existence of contagion between the US and Indian markets and urges to find the channels of the contagion effect.

Key words: Financial Crisis, Stock Market, Contagion Effect, USA & India, Bivariate GARCH-DCC Model

JEL classification: F30, G15

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1. Introduction

The housing burst in the US has led to a sequence of economic repercussions in the US and then it has got transmitted to other economies, engulfing many developed and emerging economies. The shock originated from the housing sector affected the financial sector severely as many of the insurance and investment companies dealing with the real assets and debts suffered financial losses on account of falling housing prices and loan defaults. The losses dragged them to go bankrupt and closure of the business. The attention of the policy makers got diverted from averting overheating of the world economies in the beginning of the 2007 to averting slowdown in the economies.

The closure of the activities by the construction companies and builders in the construction sector inflicted on the functioning of the downstream industries such as cement, steel and stone companies besides affecting the financial sector and other real activities. It affected the size of employment as it resulted in retrenchment and decline in income all across the sectors setting off recession.

The stock market activity is one of the principal activities in the corporate world among the chain of activities, which got affected due to the financial crisis. The stock market indices are one of the principal indicators of the economic activities. The movement of stock market indices presents the future economic outlook. A falling stock index reflects the dampening of the investment climate while a rising stock index indicates more confidence and soundness of the economy. The latter attracts more investment demand on stocks. Rising investment on stocks raises stock prices and generates profits.

When crisis affects the real activities, it affects the stock market, as profit expectation on financial investments would be lower. If financial investment would be affected, its impact would be felt on the real investment, as real investment would not increase. Once the real sector activity lessens, that would affect the entire economy. Thus, it is mainly the expectation of the investors mainly works affecting both the financial and real investment in the economy.

In India the stock market has undergone significant transformations with the liberalization measures. The Bombay Stock Exchange (BSE) of India has emerged as one of the largest

stock exchange in the world in terms of the number of listed companies, comprising many large, medium-sized and small firms. As regards transaction cost, the Indian stock market compares with some of the developed and regional economies (Raj and Dhal, 2008). The inflow of foreign capital have made a crucial contribution to the growth of the stock market. India has become a major destination, representing about a fourth of total portfolio capital inflows to the emerging market economies (EMEs) group. India has also become engaged in various bilateral trade and economic cooperation agreements with several countries and regional groups across Asia, Europe and the Western hemisphere. In this context, the concerns regarding its exposure to risk in case of the global crisis are compelling. The analysis contained in the IMF's Global Financial Stability Report (October 2008) (IMF, 2008a), finds that correlation of equity markets in EMEs with those in the advanced economies has risen, suggesting a growing transmission channel for equity price movements. Amongst the three groups of EMEs (Latin America, Asia and Emerging Europe), the spillover from global factors is found to be strongest in Latin American EMEs followed by Emerging Europe and Asia. One of the Central bankers in India, Rakesh Mohan (2008) sometimes remarked that one of the key features of the current financial turmoil has been the lack of perceived contagion being felt by banking systems in EMEs, particularly in Asia. The Indian banking system also has not experienced any contagion, similar to its peers in the rest of Asia. But this needs to be empirically verified whether it is true that India's stock market has not been affected during the crisis period.

In the literature, the integration of global equity markets has been a well-studied topic since the stock market crash of October 1987. Though most of the studies had initially been conducted for the developed markets like the US, European countries and Japan, recently, post Asian crises in particular; literature has started focusing on emerging Asian markets. A small body of literature exists in the Indian context, which predominantly depends on the bivariate and multivariate cointegration analysis. There are also many studies examining the existence of contagion effect of various crises on different stock markets in the world using different methodologies. It is observed that there are no studies in the Indian context looking at the contagion impact of the crisis affected USA stock market on India's stock market which is of a most recent issue. Therefore, the aim of this study is to test whether there exists a contagion effect of the recent crisis on Indian stock market. In order to

recognize the contagion effect, the study estimates the time-varying correlation coefficients by employing the dynamic conditional correlation (DCC) Bi-variate GARCH model of Engle (2002). The rest of the paper is organized as follows. Section 2 gives a brief overview of the literature on equity market integration and contagion effect. Section 3 narrates the methodology to estimate the conditional correlation through DCC-Bivariate GARCH model. Section 4 provides the data and empirical results. Finally, section 5 concludes.

2. Review of the Studies

2.1 Literature on Cointegration

A large body of literature exists on the equity market integration. Since the seminal work of Grubel (1968), which explained the benefits of international portfolio diversification, the relationship among national stock markets has been analyzed in a series of studies such as Granger and Morgenstern (1970), Ripley (1973), Lessard (1974,1976) and Panton, Lessig and Joy (1976) among others. Following the seminal works of Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990), numerous studies beginning with Taylor and Tonks (1989), Kasa (1992) and, subsequently, Masih and Masih (1997, 2002), Chowdhry (1994) and Chowdhry et al (2007), among several others, have used the cointegration hypothesis² to assess the international integration of financial markets. When analyzing linkages among international stock markets, it is of interest to determine if there are any common forces driving the long-run movement of the data series or if each individual stock index is driven solely by its own fundamentals; this relationship can be captured by *cointegration* analysis. When markets are said to share a single common stochastic trend, it indicates that these markets are perfectly correlated over long horizons and gains to international diversification will diminish or disappear over the long term. Kasa (1992) was the first to apply multivariate cointegration method to five well-established financial markets in order to examine the existence of a single common stochastic trend as a driver of the cointegrated system. Using Johansen's test (Johansen and Juselius, 1990), for cointegration he found a single common trend driving stock markets of US, Japan, England, Germany, and Canada, particularly when using quarterly data. According to Kasa (1992) in case of

² For a discussion on the co-integration hypothesis, see Raj and Dhal (2008)

cointegration between equity indices it is possible that gains from diversification occur in the short term but not in the long term.

Phylaktis and Ravazzolo (2002) apply Kasa's (1992) methodology and examined the potential inter-relationships amongst the trending behaviour of the stock price indices of a group of Pacific-Basin countries, Japan and US, for the period 1980 to 1998. The paper shows that international investors have opportunities for portfolio diversification by investing in most of the Pacific Basin countries since short-run benefits exist due to substantial transitory fluctuations⁵. Moreover, the estimated common trends showed that though, US markets were definitely found to play a role but small in magnitude, while Japan played a more significant role, neither Japan, nor the US had any unique influence in the Pacific Rim stock markets.

There are varied views on the after effect of the Asian financial crisis on the integration of the Asian markets. Ghosh, Saidi, and Johnson (1999) consider whether nine Asia-Pacific markets are separately cointegrated with either the US or Japanese stock market. Their results suggest that while some markets are cointegrated with the US, some are cointegrated with Japan, and others are not cointegrated with either. However, they consider daily data covering only a nine month period in 1997. Sheng and Tu (2000) discovered that the cointegration relation among 12 Pacific nations, including Taiwan and the US, did not exist in the stock markets until the 1997 Asian financial crisis occurred. The variance decomposition further showed that none of nations, during the financial crisis, had the exogenous characteristic, which verified the existence of the contagion effect. At the same time, causality tests pointed out that the US indices were the leading factors affecting the stock performance of other nations. Applying vector auto-regression (VAR) to test for causal relationship and to analyze the shock response, Nagayasu (2001) discovered the contagion effect of Thailand's currency crisis that affected the industrial indices in Philippine's stock market via foreign exchange rate

Yang and Lim (2002) in an empirical study of nine East Asian stock markets for the period January 1990 to October 2000 find some evidence of short-term linkages. Their results indicate that there was a significant difference between sub-periods pre- and (during/) post-Asian crisis, with an overall improvement of correlation coefficients for each pair from the

pre-crisis to the post crisis period, except for Malaysia and Taiwan. Unlike results from short-run tests, there is no long run comovement among East Asian stock markets, as the absence of cointegration in the post-crisis period rules out the existence of a long-term equilibrium trending relationship among East Asian stock markets.

As regards the studies in Indian context, these predominantly depend on the bivariate and multivariate cointegration analysis. The study by Kumar and Mukhopadhyay (2002) uses a two-stage GARCH model and an ARMA-GARCH model to capture the mechanism by which NASDAQ daytime returns impacts not only the mean but also conditional volatility of Nifty overnight returns. Ignatius (1992) compared returns on the BSE Sensex with those on the NYSE S&P 500 Index and found no evidence of integration. Agarwal (2000) concluded that there is a lot of scope for the Indian stock market to integrate with the world market after having found a correlation coefficient of 0.01 between India and developed markets. By using Granger causality relationship and the pair wise, multiple and fractional cointegration, Wong, Agarwal and Du (2005) have found that the Indian stock market is integrated with the matured markets of the World. Nath and Verma (2003) tested for cointegration between the Nifty, STI and Taiex and found no evidence in favor of cointegration. The recent study by Raj and Dhal (2008) uses correlation and the vector error correction and cointegration model (VECM) to gauge the integration of India's stock market with global markets such as the United States, the United Kingdom and Japan, and with major regional markets such as Singapore and Hong Kong. They examine the cointegration for the period 1993-2008 as well as for the sub-periods such as 1993-2002 and 2003-2008 with different viz., weekly and daily data sets. Empirical evidence supports the international integration of India's stock market in terms US dollars but not in local currency, a finding attributable to investment decisions of foreign investors. Correlations of daily stock price indices and returns suggest a strengthening of the integration of India's stock market with global and regional markets in the more recent period since 2003. There is evidence of the differential impact of regional and global stock markets on the Indian market in the long run as well as the short run. The absolute size of coefficients in the long-run cointegration relation suggests that the Indian market's dependence on global markets, such as the United States and the United Kingdom, is substantially higher than on regional markets such as Singapore and Hong Kong. Innovation accounting in the VECM for the more recent period

shows that international market developments at regional and global levels together could account for the bulk of the total variation in the Indian stock market.

2.2 Literature on Contagion

There is now a reasonably large body of empirical work testing for the existence of contagion during financial crises. The definition of the term contagion varies widely across the literature. Referring to World Bank classification we can distinguish three definitions of contagion viz., broad, restrictive and very restrictive definitions of contagion³. The most widely used definition in the literature is the very restrictive definition. This is the one adopted by Forbes and Rigobon (2000, 2002) (hereafter F-R). According to F-R contagion should be interpreted as a change in the transmission mechanisms that takes place during a turmoil period. The authors identify financial contagion with ‘a significant increase in cross-market linkages after a shock to one country (or group of countries)’ and defend that such definition presents a number of operational advantages. Namely, its utility for financial investors engaged in strategies of international diversification, or for monetary authorities aiming at justifying bailing out interventions in markets affected by foreign crises, but displaying sound fundamentals.

The common methods, adopted by empirical literatures to test for the contagion effect, include the analysis of market correlation coefficients, the GARCH model, the cointegration test, and the probability of event happening. Most initial empirical assessments of financial contagion were simple comparative analyses of Pearson’ correlation coefficients between markets in calm and in crisis periods. Evidence of contagion was reported when statistically significant increases in correlations occurred in periods of crisis. King and Wadhvani (1990), and Lee and Kim (1993) employed the correlation coefficient between stock returns to test for the impact of the US stock crash in 1987 on the stock markets in England, Japan, and several other countries. Empirical findings showed that the correlation coefficients between several markets significantly increased during the crash. Thus, these findings supported the

³ In broad definition contagion is identified with the general process of shock transmission across countries. The latter is supposed to work in both tranquil and crisis periods, and the contagion is not only associated with negative shocks but also with the positive spillover effects. In restrictive definition contagion has to be meant as the propagation of shocks between two countries (or group of countries) in excess to what should be expected to be explained by the fundamentals and besides considering the co-movements triggered by the common shocks (www.worldbank.org/economicpolicy/managing%20volatility/contagion/index.html)

contagion hypothesis that states “if the correlation coefficient increases significantly, the contagion effect exists.”

Later studies pointed out a number of methodological problems in linear correlation based assessments and proposed alternative approaches. F-R shows that the correlation coefficient underlying conventional tests for contagion is biased. This correlation coefficient is actually conditional on market volatility over the time period under consideration, so that during a period of turmoil when stock market volatility increases, unadjusted estimates of cross-market correlations will be biased upward. This can erroneously lead to accept that contagion occurred. They, while examining contagion and/or interdependence, explain the interdependence effect through four channels, including *trade linkages*, *policy coordination*, *country reevaluation* or *learning* and *random aggregate* or *global shocks*. This is the so-called crisis-contingent hypothesis. They further exemplified *multiple equilibria*, *endogenous liquidity*, *political economy*, and other non-pre-hypothesized channels to illustrate the transmissions through non-existent channels in stable times. To account for the bias caused by market heteroscedasticity in the simple correlation they developed an adjusted correlation coefficient. With these adjusted correlation coefficients, the authors found that there was not a significant change in correlation coefficients but interdependence effect was observed during the 1997 Asian financial crisis, the 1994 Mexican crisis, and the 1987 US stock market crisis, among 29 nations including 9 in Southeast Asia, 4 in Central and South America, 12 in OECD, and 4 other new nations.

We see also application of ARCH and GARCH models in contagion analysis. Hamao, Masulis, and Ng (1990) employed the conditional variance estimated under the GARCH model to test for correlations between market volatilities during the 1987 US stock market crisis. It was found that the spillover effects from New York to London and Tokyo and from London to Tokyo were observed among the stock markets in New York, London, and Tokyo. Edward and Susmel (2001) considered the systematic changes and adopted the switching ARCH model. They found that many Latin American equity markets, during the times of high market volatility, were significantly correlated which proved the existence of the contagion effect.

The studies prior to the Multivariate GARCH revolution use conventional econometric techniques including cointegration, causality tests and univariate GARCH models. The (G)ARCH revolution brought out the use of a number of multivariate GARCH models that provide more efficient tools for analyzing comovements and volatility spillovers between financial assets than the other methods. The estimation of Dynamic Conditional Correlation with Bi-variate GARCH has been in use since the work of Engle and Sheppard (2001) and Engle (2002). This, in fact, proved to be giving a better description of the data than the Constant Conditional Correlation GARCH model (see Cappiello, Engle and Sheppard, 2003).

Wang *et al.*, (2006) used DCC-Bivariate GARCH to examine the impact of Asian financial crisis on Chinese Economic Area (CEA). Their sample period spans from Feb. 21, 1992 to Nov. 15, 2000. The empirical findings showed that the conditional correlation coefficients of stock returns were positive, and co-movement exists among the Thailand and CEA markets. The Asian financial crisis significantly shocked the stock markets in the region. For all the markets, the variances were higher in the post-crisis period than in the pre-crisis period. The conditional correlation coefficient means in the post-crisis period increased at a significant level, providing the evidence of the contagion effect. Chiang *et al.* (2007) also apply a DCC model to nine Asian stock markets from 1990 to 2003, confirming a contagion effect. In Egert and Kocenda (2007) the bivariate version of the Dynamic Conditional Correlation GARCH (DCC-GARCH) model shed light on the strong correlation between the German and French markets and also between these two and the UK stock market for a common daily window adjusted for the observed *U*-shaped pattern for the period from June 2003 to January 2006. By contrast, very little systematic positive correlation can be detected between the French index (which was used as a benchmark for Western European stock markets) and the three Central and Eastern Europe (CEE) stock markets. Kenourgios *et al.*, (2007) apply the asymmetric generalized dynamic conditional correlation (AG-DCC) model to find the correlations of stock markets of four emerging markets namely, Brazil, Russia, India and China (BRIC) with US and UK markets during the periods of negative shocks. The AG-DCC results provide evidence for higher joint dependence during stock market crashes. When bad news hit stock markets, conditional equity correlations increase dramatically among BRIC and developed markets.

Looking at the survey of literature, it could be observed that there are no studies in the Indian context looking at the impact of the crisis affected USA stock market on India's stock market using which is a recent issue. This study examines this issue and finds whether there exists a contagion effect of the crisis on the Indian stock market. The detail of Methodology and data is explained in the next sections.

3. Methodology

In order to examine the impact of USA stock market on India's stock market, the paper estimates Dynamic Conditional Correlation under Bivariate GARCH model and compares the mean of correlation in two sub periods namely, crisis and pre crisis. We find the break points in the sample by using the Bai-Perron structural break test and use the most recent break in the series as the break occurred as a result of the US sub-prime crisis (see Bai and Perron 1998, 2003).

DCC Bi-variate GARCH is estimated by applying log likelihood estimation procedures. The details are as follows.

With the information of the pervious period, the conditional correlation between two random variables r_1 and r_2 that have mean zero can be written as:

$$\rho_{12,t} = \frac{E_{t-1}(r_{1,t}r_{2,t})}{\sqrt{E_{t-1}(r_{1,t}^2)E_{t-1}(r_{2,t}^2)}} \quad (1)$$

And letting

$h_{i,t} = E_{t-1}(r_{i,t}^2)$ and $r_{i,t} = \sqrt{h_{i,t}}\varepsilon_{i,t}$ for $i=1, 2$, where $\varepsilon_{i,t}$ is the standardized disturbance that has zero mean and a variance of one.

Substituting the above into equation (1) we get:

$$\rho_{12,t} = \frac{E_{t-1}(\boldsymbol{\varepsilon}_{1,t}\boldsymbol{\varepsilon}_{2,t})}{\sqrt{E_{t-1}(\boldsymbol{\varepsilon}_{1,t}^2)E_{t-1}(\boldsymbol{\varepsilon}_{2,t}^2)}} = E_{t-1}(\boldsymbol{\varepsilon}_{1,t}\boldsymbol{\varepsilon}_{2,t}) \quad (2)$$

Thus, conditional correlation is the covariance of standardized disturbances. In the progress of time, the stock return variance is constant and undisputable. Hence, the correlation coefficients between stock returns also vary along with time. The estimation of Engle's (2002) DCC model comprises two steps: one is the estimation of the univariate GARCH model, and the other is the estimation of the correlation coefficient. It is generally agreed that GARCH (1, 1) is enough to capture the characteristics of heteroscedasticity of stock and financial variables (Bollerslev, Chou, & Kroner, 1992).

Utilizing the conditional correlation coefficients and variances of two stock returns to parameterize the stock return covariance matrix H_t , we have:

$$H_t \equiv D_t R_t D_t \quad (3)$$

where D_t is a 2×2 diagonal matrix of the time varying standard deviations from univariate GARCH models with $\sqrt{h_{i,t}}$ on the i^{th} diagonal. R_t is a 2×2 time varying conditional correlation matrix. As indicated, the elements in D_t follow the univariate GRACH process of the following,

$$h_{i,t} = \omega_i + \alpha_i \boldsymbol{\varepsilon}_{i,t-1}^2 + \beta_i h_{i,t-1} \quad (4)$$

Using GARCH (1, 1) specification, the covariance between the random variables can be written as

$$q_{12,t} = \bar{\rho}_{12} + \alpha(\boldsymbol{\varepsilon}_{1,t-1}\boldsymbol{\varepsilon}_{2,t-1} - \bar{\rho}_{12}) + \beta(q_{12,t-1} - \bar{\rho}_{12}) \quad (5)$$

The unconditional expectation of the cross product is $\bar{\rho}_{12}$, while for the variances

$$\bar{\rho}_{12} = 1$$

The correlation estimator is:

$$\rho_{12,t} = \frac{q_{12,t}}{\sqrt{q_{11,t}q_{22,t}}} \quad (6)$$

This model is mean reverting if $\alpha + \beta < 1$. The matrix version of this model is written as:

$$Q_t = S(1 - \alpha - \beta) + \alpha(\varepsilon_{t-1}\varepsilon'_{t-1}) + \beta Q_{t-1} \quad (7)$$

where S is the unconditional correlation matrix of the disturbance terms and $Q_t = |q_{1,2,t}|$.

If $\alpha + \beta = 1$, the model is simplified as the constant conditional correlation model of Bollerslev (1990). The log likelihood for this estimator can be written as:

$$L = -\frac{1}{2} \sum_{t=1}^T (n \log(2\pi) + 2 \log|D_t| + \log|R_t| + \varepsilon'_t R_t^{-1} \varepsilon_t) \quad (8)$$

where $D_t = \text{diag}\{\sqrt{h_{i,t}}\}$ and R_t is the time varying correlation matrix.

4. Data and Results

We use stock price indices of US and India to compute the stock reruns and find the correlation between the two series⁴. BSE Sensex and NASDAQ 100 are taken as representative of Indian and US stock markets respectively. The sample period is from January, 2, 2002 till, June, 1, 2009 and excludes holidays. The indices are collected from www.econstats.com.

Table 1 contains the summary statistics of the market returns. For the entire sample India has mean returns of 0.099 minimum returns of -11.14%, and maximum returns of 15.99% with a variance of 3.11 during the period. US has mean return of 0.007%, minimum return of -10.52%, and maximum return of 12.58% with a variance of 3.18. As should be the case, during the crisis period mean return has become negative in US market and in India it has come down drastically⁵. Variances have increased significantly compared to the pre-crisis period. The skewness coefficients are positive depicting right-skewed distributions except

⁴ Stock return is computed as the logarithmic difference of closing stock price index. Letting stock return of market i in the period t as $R_{i,t}$ and the stock price index as $P_{i,t}$, $R_{i,t} = \ln(P_{i,t} - P_{i,t-1}) \times 100$

⁵ Using Bai-Perron structural break test we find 6th August, 2008 as break point occurred due to the US sub-prime crisis.

the value corresponding to the pre crisis period for India. All the stock returns are in a leptokurtic distribution as explained by the kurtosis figures, which is a common characteristic of financial variables.

Table 1: Summary statistics of the returns data

| Market | Sample | Obs. | Mean | Skewness | Kurtosis | Variance | Min | Max |
|--------|------------|------|--------|----------|----------|----------|--------|-------|
| India | Entire | 1786 | 0.099 | 0.115 | 10.22 | 3.11 | -11.14 | 15.99 |
| | Pre Crisis | 1597 | 0.105 | -0.336 | 7.308 | 2.28 | -11.14 | 8.25 |
| | Crisis | 189 | 0.056 | 0.522 | 6.01 | 10.16 | -10.96 | 15.99 |
| US | Entire | 1786 | 0.007 | 0.285 | 7.75 | 3.18 | -10.52 | 12.58 |
| | Pre Crisis | 1597 | 0.018 | 0.315 | 5.72 | 2.46 | -6.004 | 10.62 |
| | Crisis | 189 | -0.089 | 0.248 | 5.26 | 9.28 | -10.52 | 12.58 |

Looking at the actual values plot of the return series it is observed that in both US and Indian market large changes in asset prices follow large changes and small changes follow small ones (see fig.1 and fig.2). This means that current levels of volatility is positively correlated with its level during the preceding periods. This kind of phenomenon is modeled in ARCH framework. Here, as indicated earlier, we model each return series with GARCH (1, 1) model. The results of the Univariate GARCH models are presented in table 1 and 2.

Fig. 1: BSE return series

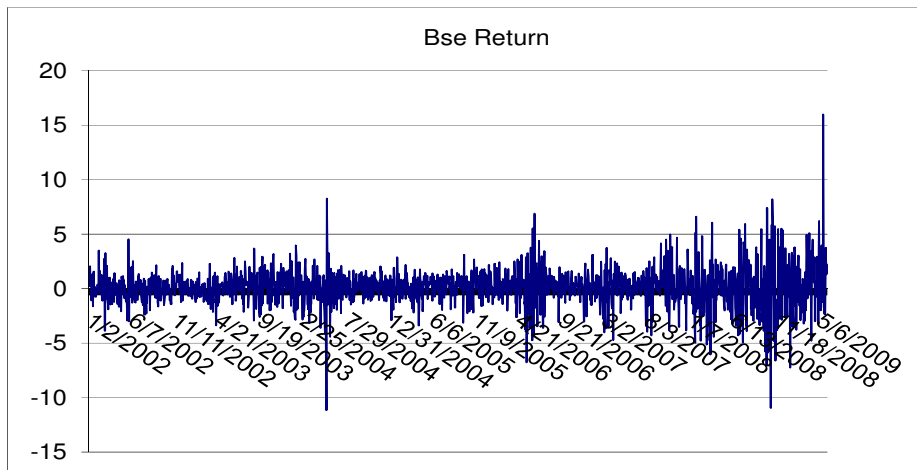
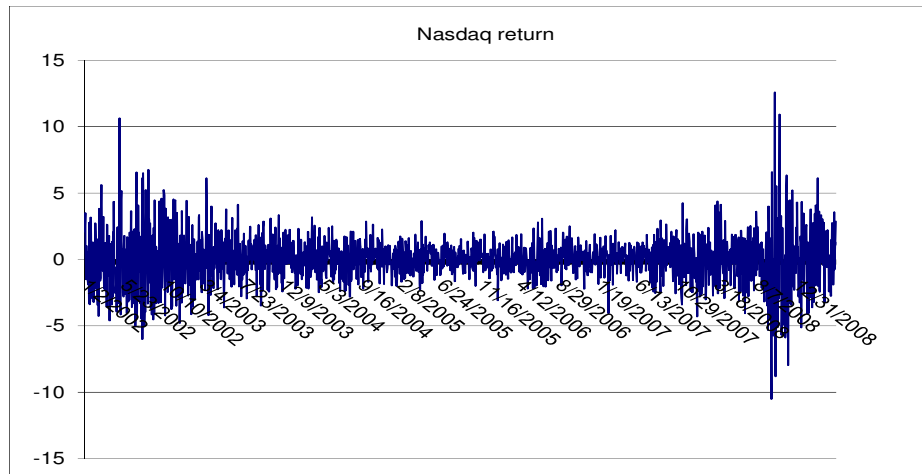


Fig.2: NASDAQ returns series



The results in Table 2 and 3 suggest that GARCH (1, 1) coefficients are found to be significant and positive, thus implying that volatility is captured by GARCH (1, 1) model. Most of the estimated parameters are statistically significant at the 1% level. The significance of coefficients in the model indicates the tendency of the shocks to persist. The sum of the coefficients of lagged squared disturbance and that of past variance [GARCH (-1)] is less than one indicating shocks die with time. The sums of the shocks are very close to 1, imply a highly persistent volatility, this phenomenon is commonly observed in practice.

Table 2: Estimation of GARCH (1, 1) Process for NASDAQ Returns

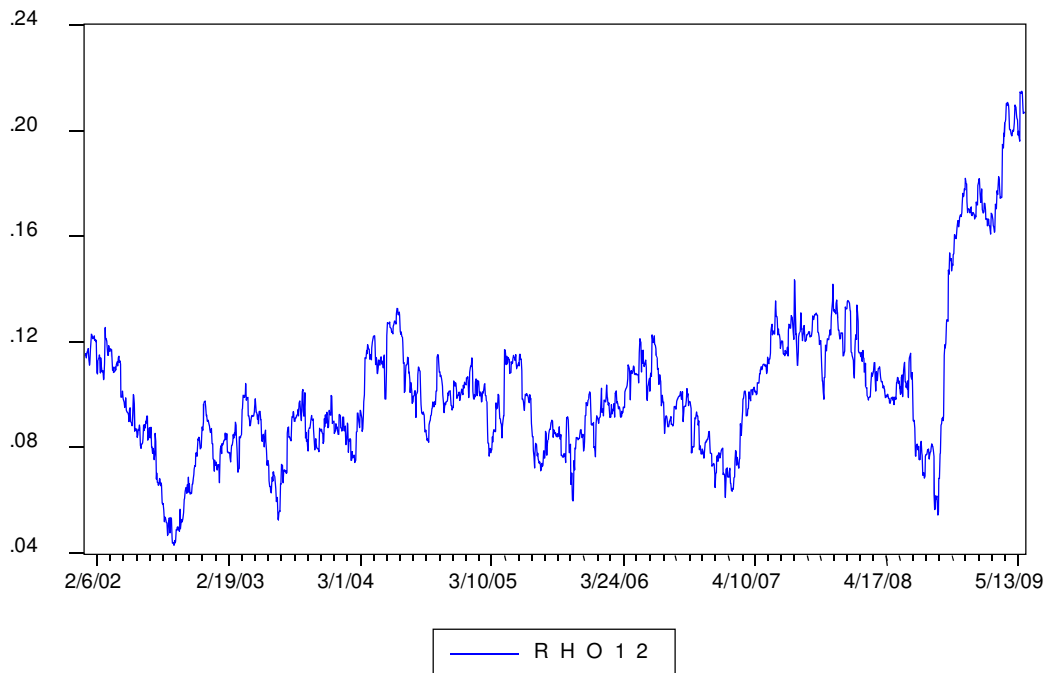
| Dependent Variable: NASDAQ Return | | | | |
|--|-------------|--------------------|-------------|--------|
| Method: ML - ARCH | | | | |
| GARCH = C(0) + C(1)*RESID(-1)^2 + C(2)*GARCH(-1) | | | | |
| | Coefficient | Std. Error | z-Statistic | Prob. |
| C | 0.052750 | 0.030472 | 1.731087 | 0.0834 |
| Variance Equation | | | | |
| C | 0.010005 | 0.005437 | 1.840257 | 0.0657 |
| RESID(-1)^2 | 0.052892 | 0.013902 | 3.804537 | 0.0001 |
| GARCH(-1) | 0.943687 | 0.012702 | 74.29226 | 0.0000 |
| Log likelihood | -3200.842 | Durbin-Watson stat | 2.163865 | |

Table 3: Estimation of GARCH (1, 1) Process for BSE Returns.

| Dependent Variable: BSE Return | | | | |
|--|-------------|--------------------|-------------|--------|
| Method: ML - ARCH | | | | |
| GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) | | | | |
| | Coefficient | Std. Error | z-Statistic | Prob. |
| C | 0.153404 | 0.029652 | 5.173517 | 0.0000 |
| Variance Equation | | | | |
| C | 0.056845 | 0.020991 | 2.708052 | 0.0068 |
| RESID(-1)^2 | 0.137523 | 0.024979 | 5.505445 | 0.0000 |
| GARCH(-1) | 0.849002 | 0.023464 | 36.18386 | 0.0000 |
| Log likelihood | -3198.511 | Durbin-Watson stat | 1.877271 | |

The standardized residuals from GARCH (1, 1) estimation and maximum likelihood method are used to estimate the mean reverting dynamic conditional correlation coefficients.

Fig.3: Dynamic conditional correlation between NASDAQ and BSE returns



The dynamic conditional correlation coefficients as seen from fig.3, in the progress of time, vary with the variation of market variances. Variances of Table 1 increase with time (variances in the post-crisis period are significantly higher than those in the pre-crisis period). The increasing variances get the unconditional correlation coefficients biased. It is clearly seen, in the entire sample period, that the unconditional correlation coefficients without consideration of variance variations in are higher than the correlation coefficients estimated by the DCC model (see Table 4). We use the t statistic to test whether the correlation coefficients between the markets are consistent in the pre-crisis and post-crisis periods. If the correlation coefficients between the two markets are significant and the null hypothesis is rejected, there is a contagion effect⁶. If the correlation coefficients are significant and the null hypothesis is not rejected, there is an interdependence relationship.

Table 4: Comparison of Unconditional Correlation and DCC

| Unconditional Correlation | | | Mean of DCC coefficients | | |
|---------------------------|--------|--------|--------------------------|--------|--------|
| Pre | Crisis | Entire | Pre | Crisis | Entire |
| 0.048 | 0.395 | 0.162 | 0.096 | 0.157 | 0.102 |

Note: all coefficients are significant at 5% level.

Table 5: t-Test for difference in mean of DCC in two samples

| <i>Sample</i> | <i>Pre-Sub prime Crisis</i> | <i>Crisis</i> |
|--|-----------------------------|---------------|
| Mean | 0.095714871 | 0.157132543 |
| Variance | 0.000339718 | 0.00196785 |
| Observations | 1596 | 188 |
| Hypothesized Mean Difference | 0 | |
| Degrees of freedom | 195 | |
| t Stat | -18.793 | |
| t Critical one-tail(5% level of signif.) | 1.652 | |
| t Critical two-tail (5% level of signif.) | 1.972 | |

Table 4 reports the dynamic correlation coefficients and unconditional correlation coefficients in pre crisis and crisis periods. This is intended to compare the difference

⁶ Here the null hypothesis is- there is no significant difference between the mean of the correlation coefficients of the sample periods and the alternative hypothesis is there is a significant difference.

between conventional unconditional and conditional correlation coefficients dividing standards may affect the conclusions about the contagion effect. The crisis period increase of the unconditional correlation coefficients stated corresponds to the increase of the post-crisis conditional correlation coefficient. But the rise in unconditional correlation is more than that in the conditional correlation. This result is consistent with the conclusions by Forbes and Rigobon (2002) that unconditional correlation coefficients are likely to support the contagion effect. The t-test for difference in mean of dynamic conditional correlation coefficients in the pre crisis and crisis period reveals that the correlation in crisis period is significantly different from the pre-crisis period (see table 5). Thus, it is evident that there is a contagion effect of US sub-prime crisis on India's stock market apart from the interdependence relationship⁷.

5. Conclusion

In this paper we have examined whether during current US sub prime there was any contagion from the US economy to India. Following Engle (2002), we estimated the Dynamic Conditional Correlation under Bi-variate GARCH⁸. The empirical finding shows that the conditional correlation coefficients of stock returns are positive, and co-movement exists between US and Indian markets. The conditional correlation coefficient mean in the crisis period increased at a significant level, providing the evidence of the contagion effect. This result is in line with the other studies of similar nature [e.g., Wang *et al.*, (2006), Kenourgios *et.al.*, (2007)]. As Kenourgios *et.al.*, (2007) put forth - when bad news hit stock markets, conditional equity correlations increase dramatically. And, policy responses to a crisis are unlikely to prevent the spread among countries since cross-market correlation dynamics are driven by behavioural reasons.

As per the 'decoupling theory' it was put forth that even if advanced countries went into a downturn, emerging economies will at worst be affected only marginally, and can largely steam ahead on their own. In a rapidly globalising world where India's integration with other economies has been increasing, the decoupling theory was never totally persuasive; given the

⁷ Though result is not reported here, we also find co-integrating relationship between the markets and this supports the interdependence relationship.

⁸ The result could have been compared with the results from the use of some methods for example, Copula models. Hence this is a first step of the analysis which could be improved further.

evidence recently - capital flow reversals, sharp widening of spreads on sovereign and corporate debt, and abrupt currency depreciations - the decoupling theory has almost completely lost credibility (Subbarao, 2008). Subbarao views that, in the advanced countries the contagion spread from the financial to the real sector but, in India, the slowdown in the real sector is affecting the financial sector, which in turn, has a second-order impact on the real sector. This needs to be examined as an extension of this paper i.e. there is need to examine further the channels of contagion effect of the crisis on the financial market and the impact of such effect on the real sector variables.

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