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Volatility Spillover in the Foreign Exchange Market: The Indian Experience

by

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Abstract

We find evidences of significant volatility co-movements and/ or spillover from different financial markets to forex market for Indian economy. Among a large number of variables examined, volatility spillovers from stock market, government securities market, overnight index swap, Ted spread and international crude oil prices to the foreign exchange market are found to be most important. Empirical findings also indicate that the volatility spillover differed across variables in terms of their influence through shocks and in terms of lagged volatility (persistence) coefficients. There are evidences of asymmetric reactions in the forex market volatility. Comparisons between pre-crisis and post-crisis periods indicate that the reform measures and changes in financial markets microstructure during the crisis period had significant impact on volatility spillover. During the post-crisis period, it is the past volatility (persistent or fundamental) changes, rather than the temporary shocks, that had significant spillover effect on forex volatility. There are evidences of decline in asymmetric response in the forex market during the post-crisis period for the Indian economy.

Keywords: Emerging financial market, exchange rate, volatility spillover, multivariate GARCH, threshold GARCH, GJR-TGARCH,

JEL Classification: G13, F31, C51

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Introduction

The exchange rate is a key financial variable that affects decisions made by foreign exchange traders, businesses, financial institutions, professional investors, and policymakers. Movements in exchange rate and its volatility have important implications for the economy's business cycle, trade and capital flows and are therefore crucial to understand financial developments and changes in economic policy.

There exist a plethora of studies on the exchange rate modelling. The forecastability of the exchange rate based on fundamentals has been debated in the economic literature and there does not appear to be a consensus that the out-of-sample forecasts of a random work model can be improved upon. While both theoretical and empirical research still explore possibilities to improve standard macro fundamentals-based exchange rate models, to explain or predict the exchange rate movement reliably (the mean equation), we concentrate on the second moment (i.e. volatility) and aims to analyze the volatility spillover from across different financial markets to the exchange rate market. Moreover, we use high frequency (daily) data and consider those financial variables that are frequently referred while quoting the day-to-day rates by the traders and market participants in the Emerging Markets (EMEs). In particular, our study concentrates on a set of variables (equity prices, short and long run rates, term spread, Ted-spread, crude prices and Dollar-index) that the traders in the forex desk closely monitor and immediately react along with other long run macroeconomic variables.

The analysis of volatility and its spillover is particularly important at this juncture, as the last decade (2000-2011) witnessed significant addition of sophisticated financial instruments and participants in the EMEs. In the Indian context, consequent to a series of reform measures initiated by the Reserve Bank of India (RBI) and Foreign Exchange Dealers Association of India (FEDAI), there has been considerable improvement in financial market microstructure in the recent years (RCF 2006). The exchange rate policy of the Reserve Bank of India in recent years has been guided by the broad principles of careful monitoring and management of exchange rates with flexibility, without a fixed target or a pre-announced target or a band. The exchange rate

(USDINR) is largely market determined, but the central bank intervenes in the market to smooth excess volatility, to prevent disruptions to macroeconomic stability and/or to facilitate optimal decision making of the market participants.

This study adds to the existing literature in several ways. To mention a few, the use of high frequency financial markets' data and Multivariate GARCH model is likely to shed light on the short run exchange rate volatility dynamics for an emerging market. Second, in the presence of a large spillover effect, a shock in one of the market could have a destabilizing impact on the forex market. From the financial stability perspective it is important to understand how the shocks propagate across the markets and how an unanticipated change in the volatility of one financial variable, in turn, affects the conditional exchange rate volatility. Third, given that one of the objectives of the Indian central bank is to smooth excess short run volatility in the foreign exchange market, the results of this study could help in identifying the relative importance of different markets in influencing the forex volatility; and finally, it also sheds light on the plausible change in the abovementioned relationships before and after the global financial crisis.

The rest of the paper is organised as follows: Section II briefs on the international literature; Section III describes the data and methodology; Section IV devotes itself on the empirical analysis & results; and Section V concludes the paper.

2. Literature

The financial market volatility has been extensively studied using ARCH-GARCH framework pioneered by Engle (1982) and further developed by Bollerslev (1986), Nelson (1991) and others. The first generation of research considers the univariate ARCH-GARCH framework to model volatility clustering and pooling in different segments of financial markets in isolation, rather than considering the spillover from other segments of the financial markets. The second generation of models marked a departure from the large number of univariate volatility model to a multivariate framework, which explicitly accounts for volatility spillover between markets and assets. These studies generally used a multivariate-GARCH framework to model the conditional variances and co-variances across financial markets. The most widely used model in this class are VECH model (Bollerslev, Engle & Wooldridge (1990)) and the BEKK

model of Engle and Kroner (1995); these models differ in their assumptions and specifications of the variance-covariance matrix, but they help in modelling time varying variance and covariance estimates.

The financial literature postulates many possible reasons for such volatility spillovers across markets. Ross (1989) notes that apart from the information contained in prices themselves, volatility is also an important source of information in the financial markets. The first channel of volatility spillover is because of the common factors / news that affect a set of financial variables (Bollerslev.et.al (1992)) simultaneously. It states that if there are fundamental linkages between the markets, variation in the common factors is likely to cause volatility spillover across markets. The second channel operates through the information spillover caused by the cross market hedging Ederington & Lee (1993).The contagion hypothesis notes that agents who observe a price decline in one market becomes more risk averse and reduces their position in the other markets and thereby creates an apparent spillover effect (Ebrahim 2000).

There have been several applications of the volatility spillover model in the literature. To refer the most important ones, a large body of literature concentrated on the volatility spillover in the stock markets. These studies considered (a) volatility spillover from one country / world index to another (Brailsford (1996), Ng (2000)) (b) volatility spillover across indices (Kanes (1998), Beirne (2010)) and (c) volatility spillover from one script to another script/index. A second body of literature analyzed volatility spillover from spot to futures market and vice-versa. For instance, Tse and Booth (1995) study the relationship between US Treasury bill and Eurodollar futures, Tse (1999) studies the volatility spillover between DJIA spot and Futures market, while Kuo, Hsu & Chiang (2008) study whether and how the opening of foreign investment (FI) affects information transmission between futures and spot markets in terms of volatility spillover. These studies generally found evidences of volatility spillover between futures and spot markets. Furthermore, Kho.et.al (2008) results suggest that increased participation of FI in emerging futures market may enhance the rate of information flows and improve the quality and reliability of information transmission in local futures market.

Finally, there are several studies that analyze volatility spillover across different markets. Ebrahim (2000) uses a tri-variate GARCH model to investigate information transmission between foreign exchange and money markets in Canada and finds that there are significant

spillovers in the conditional means and variances in foreign exchange and money markets returns. Agren (2006) finds strong evidences of volatility spillover from oil (crude) prices to stock markets in Japan, Norway, U.K. and USA. Chulia and Torro (2008) indicate existence of bi-directional volatility spillover between Euro stock and bond futures markets. Kanas (2000) results indicate that volatility of home stock return is a significant determinant of the volatility of exchange rate changes for the USA, the UK and the Japan. Finally, Fedorova and Saleem (2008) study concentrates on the volatility spillover between Emerging Eastern European countries (Poland, Hungry, Russia and Czech Republic) and found evidence of direct linkage between the equity markets and currency market.

In the context of Asian Emerging Markets, such volatility spillover studies have been limited. In the Indian context, there have been a few studies that analyzed the role of volatility spillover from the international stock market to the domestic market in the post liberalization period (Apte (2003), Nath(2007)). In the context of domestic financial market inter-linkage and volatility spillovers, Badrinath and Apte (2003) examined the inter-linkages between stock market, money market and foreign exchange market and found evidences of volatility spillover across these markets; their study is based on daily returns data for the period January 1993 to December 2001. However, as the findings of Ghosh & Bhattacharya (2009) indicate, there has been a sea change in the Indian financial market microstructure in general and money market in particular since 2004, which has significantly changed the inter-linkages and behaviour in the Indian financial market. In the volatility spillover context, another study by Mishra et. al. (2007) used daily data up to 2003 analyze volatility spillover between stock market and foreign exchange market in India. However, rather than using a multivariate GARCH framework, Mishra et. al. estimate different order AR-GARCH to model volatility in different financial markets. In the second stage, the authors test for volatility spillover in the co-integration framework. Their results indicate that there exist a significant bi-directional volatility spillover between the Indian stock market and the foreign exchange market, and suggest that there is a long run relationship between two markets' volatility and both the market move in tandem with each other. Finally in a recent study, Behera (2011) investigated the onshore-offshore linkage of the rupee using multivariate GARCH technique. It indicates that the Non-Deliverable-Forward market (NDF) shocks and volatilities influence the onshore markets.

With this background, our study contributes to the literature in the two important ways: first, it empirically evaluates the contribution of a large number of financial markets variables (both domestic and international) to the exchange rate volatility in India, where the financial market microstructure has undergone a sea change over the past decade; and second, it compares the change in such volatility spillover in the pre-subprime crisis period to post subprime crisis period for a country, which was not directly impacted by the crisis but underwent large decline in the financial capital flows from its developed counterparts. Moreover, India also introduced large number of financial instruments, reforms during the crisis period to strengthen its financial markets. Our study sheds light on the changes in the spillover relationship as a result of the reform measure introduced in the economy, especially in the post crisis period.

3. Data and Methodology

3.1 Data

The main data source for this study is Datastream (Reuters). Daily data for financial markets variable from January 2003 to March 2012 have been used for this study. The financial markets variables considered include the Rupee-Dollar exchange rate (EXRATE), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1)[1], Ted Spread (Ted spread, has been widely used as the indicator of underlying risk in the financial markets especially in the post crisis period (e.g. ECB Annual report, Monthly reviews, and BIS publications), in the Indian context it is defined as three-month MIBOR[2] and the three-month T-bill interest rate; TEDSPD), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). In the international context, the Dollar-Index (USDX)[3] and the international crude oil prices (WTI per barrel) have been used to analyse their spillover effects

[1] In the Indian context term spread has been used as an indicator of monetary policy tightness, Prasad and Ghosh (2005), Ghosh and Ghosh (2006).
[2] MIBOR, Mumbai Interbank offer Rate, Published by National Stock Exchange and FIMMDA.
[3]The US Dollar Index (USDX) is an index (or measure) of the value of the United States Dollar relative to a basket of foreign currencies. It is a weighted geometric mean of the Dollar's value compared only with, Euro (EUR), 58.6% weight, Japanese Yen (JPY) 12.6% weight, Pound Sterling (GBP), 11.9% weight, Canadian Dollar (CAD), 9.1% weight, Swedish Krona (SEK), 4.2% weight and Swiss Franc (CHF) 3.6% weight. USDX goes up when the US dollar gains "strength" (value) when compared to other currencies.

on Rupee-Dollar exchange rate. Figure 1 (Annex) indicates the time path of these variable and Table – 1 reports the descriptive statistics. A common feature of these variables, as indicated in the Figure-1, is abnormal movements during the period September 2008 for around a year, which was mainly on account of the recent global financial crisis. Some of these variables also indicated non-stationary behaviour. The stationarity test based on the Augmented Dickey-Fuller methodology indicated presence of unit root in exchange rate, BSE index, Gsec, OIS rate and WTI in their levels. The returns of these variables (or first difference for GSEC and OIS) are therefore used for the volatility analysis (Figure 2).

Our analysis considered the pooled period (Jan 2003 to March 2012) and two sub periods. For the entire period, a dummy variable (crisis_dum) is used in the volatility equation, which took value one for the crisis-period and zero otherwise. The crisis period started from the collapse of Lehman Brothers (Sep 15, 2008) and was considered still end October 2009, when the Mid-term review of the Monetary Policy Statement (of the Reserve Bank of India) noted the need to "exit" from the crisis period conventional and unconventional policies in a "calibrated way", and the 'exit' process started with the closure of some special liquidity support measures that were announced during the crisis period. Thus the "pre crisis period" is considered from January 2003 to September 15, 2008 and the "post crisis analysis" is considered from November 2009 to March 2012.

3.2 Methodology

As mentioned earlier, most of the volatility models that have been used in the empirical literature are univariate in nature. The multivariate GARCH (MVGARCH) model makes a departure from the univariate analysis and considers volatility co-movement / spillover between markets (or assets). So MVGARCH explicitly models time varying covariance between two markets. The mean equation for our study is specified as under:

$R_{it}= \mu_i + u_{it}$, (i=1,2) and $u_t /I_{t-1}\sim N(0,H_t)$

Where u_{it} is the conditional error term, and H_t represents the conditional variance at time 't'

The specification of the variance and covariance matrix in VECH model is given as follows:

$VECH(H_t)=C+A*VECH(\Xi_{t-1}\ \Xi'_{t-1})+B*VECH(H_{t-1})$

$H_t = \begin{bmatrix} \text{hiit} & hijt \\ hjit & hjjt \end{bmatrix}$ $\Xi_t = \begin{bmatrix} \varepsilon 1t \\ \varepsilon 2t \end{bmatrix}$ $A = \begin{bmatrix} a11 & \cdots & a13 \\ \vdots & \ddots & \vdots \\ a31 & \cdots & a33 \end{bmatrix}$ $B = \begin{bmatrix} b11 & \cdots & b13 \\ \vdots & \ddots & \vdots \\ b31 & \cdots & b33 \end{bmatrix}$

In this context VECH(H(t))= $\left\| \begin{matrix} \text{h11t} \\ \text{h22t} \\ \text{h12t} \end{matrix} \right\|$ and the expanded VECH($\Xi_{t-1}\ \Xi'_{t-1}$)= $\left\| \begin{matrix} \text{u1t} - 1 \\ \text{u2t} - 1 \\ \text{u1t} - 1 * \text{u2t} - 1 \end{matrix} \right\|$

Where a_{ij} measures the shock spillover and b_{ij} measures the past volatility spillover.

So the conditional variance and conditional covariance depend on the lagged values of all the conditional variance and covariance (between the two assets) as well as lagged square error and error cross-products. Several different multivariate GARCH formulations are proposed, which deals with the variance-covariance matrix differently (under different assumptions). For instance, Bollerslev, Engles and Wooldridge (1988) proposed a model where 'A' and 'B' matrices are assumed to be diagonal (diagonal-VECH model), which is given by

$h_{ijt}=c_{ij}+a_{ij}\ u_{i,t-1}\ u_{j,t-1}+b_{ij}\ h_{ij,t-1}$ for j,i=1,2

Under assumption of conditional normality this system of equations can be estimated by maximizing the likelihood function. However the Multivariate-GARCH estimation introduces additional complexity and extra parameters as compared to its univaraiate counterpart. With the increase in the number of variables (Markets or assets), the number of parameters and consequently the estimation of such models become difficult. In view of the above our study uses bi-variate MVGARCH model and use diagonal-VECH specification to estimate the same. We compare the robustness of the result also by estimating the BEKK (Engle and Kroner (1995) methodology[4].

Finally, the literature has documented that volatility spillover between the financial markets could be asymmetric and sited two main reasons for asymmetric volatility responses. The first is based on the *leverage effect hypothesis*, which notes that a drop in the value of the stock increased the leverage and therefore makes the stock more risky and consequently increasing the volatility (Black 1976, Christie, 1982). The second one, commonly referred as the *volatility spillover hypotheses*, suggest that the asymmetric volatility is a consequence of return incorporating time varying risk premium. Though, the existence of asymmetry has been well

[4] For a detailed discussion on Multivariate GARCH, see Brooks (2008) and Bauwens (2006).

documented the volatility models, the literature remains ambiguous about which of these two effects dominates the asymmetric financial market volatility, To account for such asymmetric response to a negative shocks, we use *GJR model (*also known as a variant of Threshold GARCH or TGARCH*)*, which is a simple extension of the above GARCH model. It include an additional term I_{t-1}, which takes value one (if $u_{i,t-1}<0$, $u_{j,t-1}<0$; for j,i=1,2). In the presence of asymmetric impact the GJR-coefficient of I_{t-1} takes a positive and significant value. The augmented MVGARCH with diagonal VECH and GJR (or TGARCH) coefficient is as under:

$$h_{ijt}=c_{ij}+a_{ij}*u_{i,t-1}\,u_{j,t-1}+b_{ij}*h_{ij,t-1}+d_{ij}*u_{i,t-1}\,u_{j,t-1}*\,I_{t-1}+\,e_{ij}*\text{Crisis_dummy}$$

for j,i=1,2 and the GJR variable $I_{t-1}=1$, if $u_{i,t-1}<0$ and/or $u_{j,t-1}<0$ (for j,i=1,2);

where crisis dummy takes the value 1 for the period Sep 15, 2008 to October 27, 2009.

The last term (e_{ij} *Crisis_dummy) appears in the pooled estimation, where e_{ij} coefficient indicates the effect of crisis on the financial markets variable and the spillover coefficients.

4. Empirical Results

We first test for the presence of time varying volatility clustering for the select set of variables (as indicated in section 3.1) pertaining to Indian financial markets. The LM-test for the ARCH effect confirms that the selected set of variables exhibit volatility clustering. This is in line with the finding of several studies for the developed financial markets (for a survey Bollerslev, Chou, Kroner, 1992) and Indian financial market (Thenmozhi, 2002; Raju and Karande, 2003, Bandivadekar and Ghosh, 2003, Apte (2003), Behra(2011)), which indicate presence of volatility clustering in the Indian financial time series. Our select variables from international financial markets (i.e. return on Dollarindex and return on crude) also indicate presence of ARCH effect.

We thereafter evaluate volatility co-movements and/or volatility spillover to forex market from each of the other segments of the domestic financial markets and international markets by analyzing the volatility co-movements / spillover in bivariate-GARCH framework. In this model, one of the variables is the daily returns from Rupee-Dollar exchange rates and the other variable is each of different financial markets' rates and/or returns. The result of each of the estimations is reported in this Table 1A for the entire period (Jan 2003 to March 2012) under consideration.

These results confirm the volatility clustering and pooling (ARCH) effect as almost all of the coefficients (*A(i,j)* and *B(i,j))* in the variance equation are significantly different from zero at the conventional levels. Furthermore, there are strong evidences of volatility co-movemetn as the cross coefficient are found to be significantly different from zero. The coefficients *a(1,2)*, that measured the shock (u_{it-1}) spillover are found to be statistically significant below 5 per cent level for all the pairs except the returns on the Dollar-Index (USDX), which also reported the lowest *a(1,2)* coefficient. The *a(1,2)* coefficient is maximum for the stock return (RBSE) followed by the 3-month forward premium, and the Ted-Spread. On the other hand, the coefficients *b(1,2),* which measure the volatility ($h_{ij,t-1}$) spillover, are significantly different from zero (below 5 percent level) for all the variables. *B(1,2)*, which measures the impact of past volatility, recorded much larger coefficient value (as compared to the *a(1,2)*) and the Return on Dollar-index (RUSDX) has the highest value. The RUSDX-coefficient is followed by coefficient of differenced benchmark rate (DGSec), differenced one year OIS rate (DOIS)[5] and the return on crude oil prices (RWTI). These results (a) confirms the findings of few studies on India that found evidences of volatility spillover in Indian finance markets in general (Apte (2003), Behra(2011) and in forex market in particular (b) clearly indicates that past shocks and conditional volatility in different segments of financial markets in India plays an important role in influencing the forex volatility clustering in Indian financial markets and (c) indicates that different variables have different impact in shock (u_{it}) spillover and in past volatility ($h_{ij,t-1}$) spillover, through which they affect the forex volatility. For instance while past volatility in Dollar-index return and crude (WTI) return played an important role, it was forward premium and Ted-spread, which influenced the shock spillover most. These findings shade light on the variable that perturbs exchange rate volatility in the short run from those, which have more persistent / enduring impact on the forex rate volatility.

Next, we turn to the coefficient of the dummy variable in the pooled regression. The *E(1,1)* coefficient are generally positive and significant indicating the increased volatility during the crisis period. The *E(1,2)* coefficients, on the other hand, are mostly found to be insignificant. Some of the *E(2,2)* coefficients are found to be positive, while some of the *E(2,2)* coefficients

[5] For Gsec and OIS the first differences of these variables were used as they were found to be non-stationary for the time period under consideration. However, in view of the relevance of the rate variables (Gsec and OIS1Y), we re-estimated the model in the levels (Gsec and OIS1Y) rather than in their differenced form. The results in general supporte the spillover of volatility as A(i,j) and B(i,j) coefficient are positive, significant and comparable in both cases.

are significant and negative (for instance, one year OIS, or the forward premium coefficients), indicating marginal reduction in volatility through these route. All-in-all, the coefficients indicate the change in the underline volatility dynamics during the crisis period and note the need for more detail analysis of the changes in underlined dynamics during the pre-crisis and post-crisis period[6].

Finally, though the Diagonal-VEC estimates the impact of lagged cross error term (u_{it-1}) and past volatility ($h_{ij,t-1}$) on the present cross volatility and the coefficients A(i,j) and B(i,j) have been referred in the literature (Brooks (2008)) as the volatility spillover, it remains silent on the causal relation and the direction of volatility spillover. To shed light on this issue, we followed a two step process, where in the first stage we estimate uni-variate GARCH (1,1) and conditional volatility for each of the markets; and in the second stage we test for the existence of causal relationship among these conditional variances using Granger causality test. The optimal lag length for the test is found to be 4 using AIC Criterion. However, the F-Statistics obtained with the lag length 3 and 5 also confirm the results. The Granger causality test results indicate presence of unidirectional causal relation from BSE (returns) volatility, Dollarindex (returns) volatility, WIT crude (returns) volatility and OIS volatility to Forex Volatility. Moreover, bi-directional causal relation between GSEC rate volatility and Forex return Volatility, TEDSPD volatility and Forex return Volatility and between Spread volatility and forex return volatility were found to be statistically significant. These results support and strengthen the finding of the Multivariate GARCH results obtained above.

4.1 Volatility Spillover from Financial Market to Forex Market during the pre-crisis and post-crisis periods:

The financial landscape has changed significantly after the collapse of Lehman Brothers in September 2008. An important lesson learnt, in the post-September 2008, is that irrespective of the degree of globalisation of a country and the soundness of its domestic policies, a financial crisis could spread to every economy (Mohanty 2009). Though the sub-prime crisis didn't impact the financial markets in India directly, the crisis affected the financial markets through withdrawals of foreign equity investment in India and put pressure on the dollar liquidity in the

[6] In an alternative specification we have also estimated the above pooled model after introducing the 'crisis dummy' in the mean equation. In the mean equation the coefficients of the crisis dummy were found to have the expected signs and were significant for call rate, spread, Ted Spread and forward rate. The estimated results of the GARCH specification had significant A(i,j) and B(i,j) coefficients and strongly supports observation relating to volatility as reported in the above paragraphs.

domestic foreign exchange market. Policy makers in India reacted with both conventional and unconventional monetary policy measures, and also with long term measures like introduction of several new financial instruments, more emphasis on financial stability in the policy stance. In the post crisis period, some of the new financial instruments introduced in Indian financial markets include, currency derivatives (in US Dollar) in August 2008, interest rate futures in August 2009, currency futures in Yen, Euro and GBP in January 2010 and Marginal Standing Facility (MSF)[7]as a new operational tool for monetary policy in May 2011. The sub-prime crisis, on the other hand, also brought to fore the resilience of Indian financial system, well capitalized banking system, renewed investors' confidence, which resulted in quick recovery of the Indian economy from the crisis.

To understand the impact of the sub-prime crisis, the new instrument and their impact on volatility spillover relation between the foreign exchange market and other financial variables, we re-estimate the same set of MVGARCH models for the pre-crisis period (Jan 2003 to September 15, 2008) and the post-crisis period (October 2009 to March 31, 2012) and the re-estimated coefficients are reported in the Table 2A and Table 3A respectively.

The above tables indicate the presence of ARCH-effect for both the periods; most of the coefficients in the volatility equation are significant during the pre-crisis and the post-crisis periods. In particular, the coefficient *a(1,2)* and *b(1,2)* are all significant at one per cent level in the pre-crisis period. The magnitude and significance of the cross coefficient indicate that the stock market return (RBSE) has important influence on forex volatility spillover, and influence the latter through both the shocks (u_{it}) and the past volatility ($h_{ij,t-1}$) routes during the pre-crisis period. These findings are in line with Kanas (2002) and Fedorova & Saleem (2008), where the authors emphasise the role of home stock market volatility in influencing the exchange rate volatility. Among the other factors that had high coefficient values are differenced-benchmark-yield-volatility, the Ted-spread-volatility and the differenced-one-year-OIS rate volatility.

In the post-crisis period, the presence of the ARCH effect were confirmed by the significance of *a(i,i)* and *b(j,j)*. However, among the cross terms *b(i,j),* the changes in Gsec rate (DGsec), the changes in one-year OIS rate (DOIS), the stock exchange return and the international crude price return reported high coefficient values.

[7]Banks can borrow overnight from the MSF up to one per cent of their respective net demand and time liabilities or NDTL. The rate of interest on amounts accessed from this facility will be 100 basis points above the repo rate.

One important finding is that most of the *a(i,j)* coefficients, which are found to be statistically significant during the per-crisis period, are found to be statistically insignificant during the post-crisis period (with an exception of the stock return term, which is found to be statistically significant in both the periods). The Table-1 presents the estimate of the MVGARCH model coefficient for the pre-crisis period and post-crisis periods. The coefficients reported in Table-1 support the findings of the Antoniou and Holmes (1995) and Bologna and Cavallo (2002) study. It shows that in the GARCH variance-equation, the *a(i,j)* components have mostly become statically insignificant, whereas most of the *b(i,j)* components estimates are significant at five per cent level[8]. Both Antoniou and Holmes (1995) and Bologna and Cavallo's (2002) studies have referred *a(i,j)* as the effect of 'recent news' and *b(.i,j)* capturing the effect of 'old news', persistence of a shock, or more fundamental changes. Thus, the result reported in Table-1 indicate that the post crisis period have actually increased the spillover impact of "old" or persistent news and at the same time reduced the uncertainty originating from the sudden and temporary shocks. This could be an indication of the deepening / maturing of the Indian financial market, which could have been the result of financial market related policies, introduction of new instruments or both.

[8] It may be mentioned here that the a(i,j) are the coefficient of square of the error term and the b(i,j) that represents the coefficient of the lagged variance term in the MVGARCH covariance equation.

Table 1: Spillover Effects

	Pooled Data	Pre-Crisis	Post-crisis	Pooled Data	Pre-Crisis	Post-crisis
	A1(1,2)	A1(1,2)	A1(1,2)	B1(1,2)	B1(1,2)	B1(1,2)
RBSE	0.0821	0.1012	0.0430	0.8983	0.8443	0.8910
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CALL	0.0457	0.0772	0.0329	0.8237	0.6021	0.8387
	(0.00)	(0.04)	(0.28)	(0.00)	(0.00)	(0.00)
DGSEC	0.0220	0.0191	0.0191	0.9622	0.9552	0.9239
	(0.00)	(0.11)	(0.19)	(0.00)	(0.00)	(0.00)
SPD1	0.0497	0.0777	0.0305	0.7289	0.6794	0.8551
	(0.02)	(0.04)	(0.35)	(0.00)	(0.00)	(0.00)
TEDSPD	0.0549	0.0661	-0.0014	0.7043	0.7302	-0.0153
	(0.02)	(0.04)	(0.98)	(0.00)	(0.00)	(0.98)
DOIS1Y	0.0335	0.0395	0.0185	0.9271	0.7876	0.9130
	(0.00)	(0.16)	(0.38)	(0.00)	(0.00)	(0.00)
FWD3M	0.0622	0.1267	0.0502	0.3430	0.4376	0.0387
	(0.03)	(0.01)	(0.37)	(0.00)	(0.02)	(0.93)
RUSDX	0.0094	0.0533	0.0533	0.9783	0.6887	0.6887
	(0.08)	(0.36)	(0.36)	(0.00)	(0.05)	(0.05)
RWTI	0.0436	-0.0155	0.0180	0.9078	0.8046	0.8960
	(0.00)	(0.50)	(0.31)	(0.00)	(0.00)	(0.00)

Note: Rupee-Dollar exchange rate (EXRATE/INRUSD), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1), Ted-Spread (difference between three-month MIBOR and the three-month T-bill interest rate, TED), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). Dollar-Index (USDX) and the international crude oil prices (WTI per barrel). The US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies.
P-values of the coefficients are reported in the parenthesis.

Finally, we consider the Threshold-GARCH coefficient or the *D(i,j)* coefficient. The Table for pooled (2A), pre-crisis (3A) and the post-crisis (4A) indicates that the *D(1,2)* and *D(2,2)* coefficients are not generally statistically significant. However, most of the *D(1,1)* coefficients are significant during the pooled and pre-crisis periods. The *D(1,1)* coefficients generally represent the asymmetric impact of volatility in the foreign exchange return equation. In the Indian context (the direct exchange rate[9]) a positive return indicates the relative rupee depreciation and the error term in the mean equation took negative value when such rupee

[9] It involves quoting in fixed units of foreign currency against variable amounts of the domestic currency. For instance $1=INR 53.40 is a direct quote for USDINR exchange rate.

depreciation was lower than the average depreciation during the period under consideration. The negative *D(1,1)* coefficient therefore indicated that volatility increased with higher depreciation of rupee as compared to below average depreciation. However, this asymmetric response seemed to have faded out in the post crisis period as most of the *D(1,1)* coefficients were found to be statistically insignificant during Nov 2009 to March 2012. This result could indicate better informed responses by the market, which has reduced the asymmetry in the Indian foreign exchange market.

4.2 Robustness test

To test how the model-fits the data, we test the residual for autocorrelation using residual *Portmanteau Test* for autocorrelation (with both ordinary and standardized residuals) up to 12 lags, and the Null Hypothesis 'no residual autocorrelation up to lag h' could not be rejected for most of the lags in the pre-crisis and post-crisis periods.

Given the large number of daily observations, the error distribution was assumed to be multivariate normal, while estimating the coefficients of the MVGARCH equations. To test the robustness of the above results, we re-estimated the MVGARCH model assuming multivariate *Student's t* error distribution. The estimation results were consistent with those obtained (and reported) with the multivariate Normal distribution.

Finally, one of the criticisms with the VECH-model is that the resulting 'A' and 'B' matrix may not be positive semi-definite (PSD). To address this criticism, we re-estimated the model using BEKK methodology and the covariance path (chart) for the pair of variables indicated time varying plot, confirming the spillover of volatility from other financial markets to the forex market.

5. Conclusions

The exchange rate volatility has been a major policy variable because a key macro-variable like the exchange rate affects optimal decision making of the economic agents in the real and financial sectors. Central banks (like Reserve Bank of India) attempt to curb excessive volatility and restore orderly conditions to ensure that exchange rate volatility does not impair on the macro-economic stability. Given such an important role for exchange rate volatility, our study attempts to evaluate the volatility co-movements and/or spillovers from other financial

market segments to forex market and analyze any possible change in the relationship over the past decade.

Using daily data, we analyze a large number of financial markets variables from January 2003 to March 2012 in a multivariate GARCH framework and find evidences that volatility actually spilled over from stock market, govt. securities (Gsec) market, forward market, derivative market (OIS) and international crude prices to forex market. The market risk appetite represented by Ted-Spread volatility also had an important influence on forex volatility. Stock market volatility emerged as the most important factor influencing volatility spillover in the forex market. This is intuitive, and indicates the fact that over the past few years the USD-INR volatility has been mainly influenced by capital flows in the Indian stock markets. The stock market volatility spillover is followed by spillover from the Gsec market, OIS market, Ted-Spread and from the international crude prices.

A comparison of the spillover relationship from financial markets to forex market indicate that during the post-crisis period the temporary shock coefficients (*a(i,j)* coefficient in the covariance equation) have become statistically insignificant for most of the financial variables, while the coefficients of past volatility co-variance (*b(i,j)* coefficients in the covariance equation) have increased in value and in statistical significance. These results could indicate the importance of persistent deviation (fundamental shocks) in the post reform period rather than the role of temporary disturbances in the volatility spillover to the forex market. There have also been reductions in the asymmetric response in the forex market volatility in the post-reform period as compared to the pre-reform period.

Given that there have been considerable reforms, introduction of several new financial markets instrument and renewed emphasis on financial stability in India in the post-crisis period, the above findings could indicate improved market microstructure in the Indian financial markets over the recent years. Today, a large body of literature shed light on issues such as transmission of information between market participants, heterogeneity of agents' expectations and the implication of such heterogeneity for trading volume and exchange rate volatility. While our study finds empirical support in this direction, future studies might consider addressing issues relating to market microstructure development and time varying volatility and/or on relationship between volatility, trading volume, bid-ask spread for the emerging market economics.

Table 1A: Descriptive Statistics

	Exrate	BSE	CALL	GSEC	SPD1	TEDSPD	OIS1Y	FRW3M	USDX	WTI
Mean	45.7	11251.2	5.8	7.3	1.1	1.3	6.2	3.2	86.2	63.9
Median	45.6	11604.5	5.7	7.5	0.9	1.1	6.1	2.9	84.4	63.2
Maximum	53.7	21005.0	70.0	9.5	3.6	4.7	10.2	9.0	120.2	145.7
Minimum	39.3	2834.4	0.01	5.0	-0.9	-0.2	3.7	-2.3	71.3	18.0
Std. Dev.	2.8	5687.0	2.5	1.0	0.9	0.9	1.3	2.2	10.4	26.9
Skewness	-0.2	-0.1	9.3	-0.7	1.1	1.3	0.3	0.4	1.3	0.4
Kurtosis	3.1	1.5	200.7	2.8	3.8	4.6	2.4	2.6	4.5	2.5
Jarque-Bera	23.0	240.6	4391046.0	209.2	647.9	1110.4	90.6	104.1	1031.5	85.1
Probability	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Observations	2672.0	2672.0	2672.0	2672.0	2672.0	2672.0	2672.0	2672.0	2672.0	2672.0

Note: Rupee-Dollar exchange rate (EXRATE/INRUSD), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1), Ted-Spread (difference between three-month MIBOR and the three-month T-bill interest rate, TEDSPD), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). Dollar-Index (USDX) and the international crude oil prices (WTI per barrel). The US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies. It is a weighted geometric mean of the dollar's value compared only with, Euro (EUR), 58.6% weight, Japanese yen (JPY) 12.6% weight, Pound sterling (GBP), 11.9% weight, Canadian dollar (CAD), 9.1% weight, Swedish Krona (SEK), 4.2% weight and Swiss Franc (CHF) 3.6% weight. USDX goes up when the US dollar gains "strength" (value) when compared to other currencies.

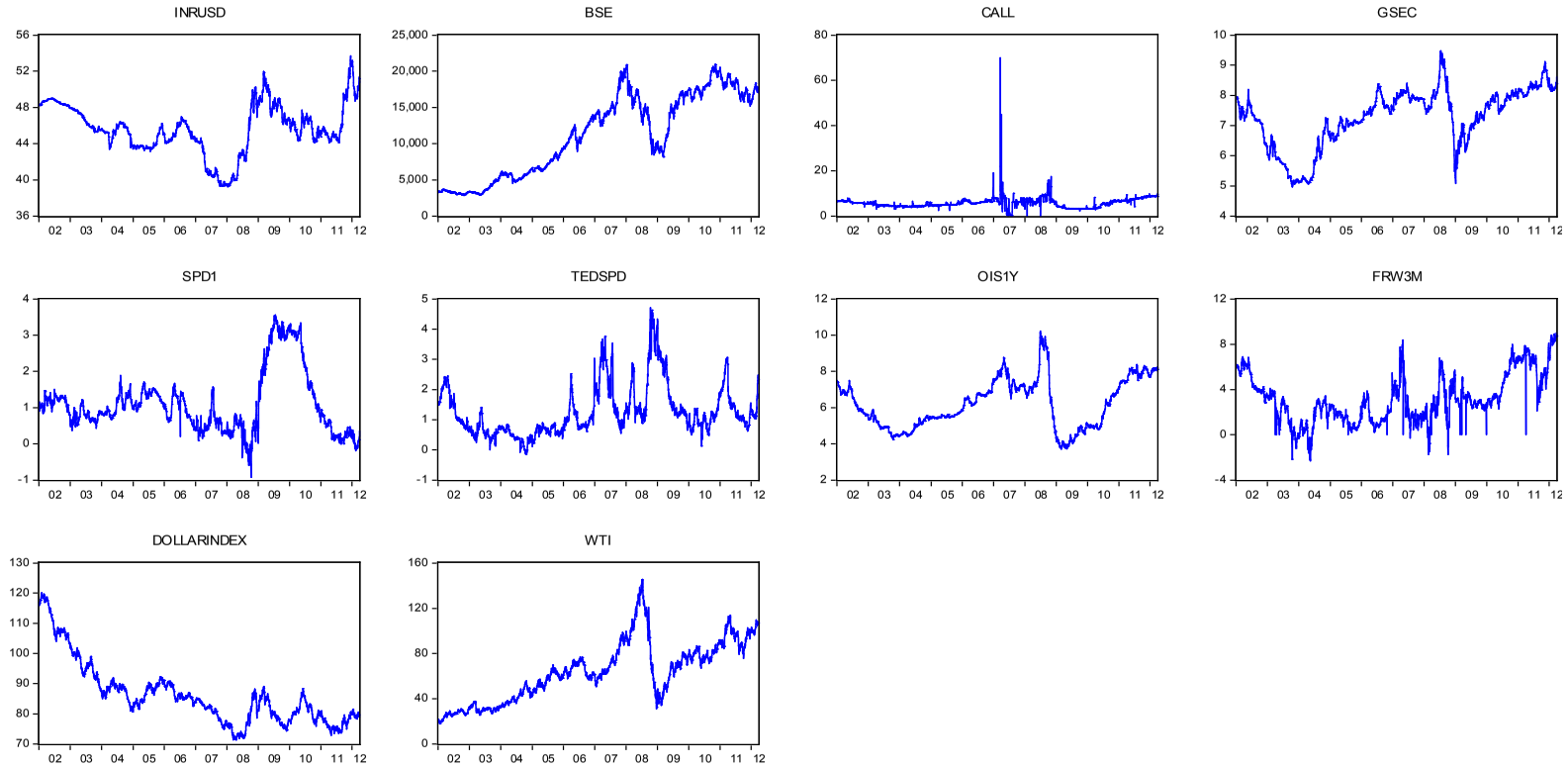

Figure 1: Time Path of the Financial Variable

Note: Rupee-Dollar exchange rate (EXRATE/INRUSD), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1), Ted-Spread (difference between three-month MIBOR and the three-month T-bill interest rate, TEDSPD), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). Dollar-Index (USDX) and the international crude oil prices (WTI per barrel). The US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies.

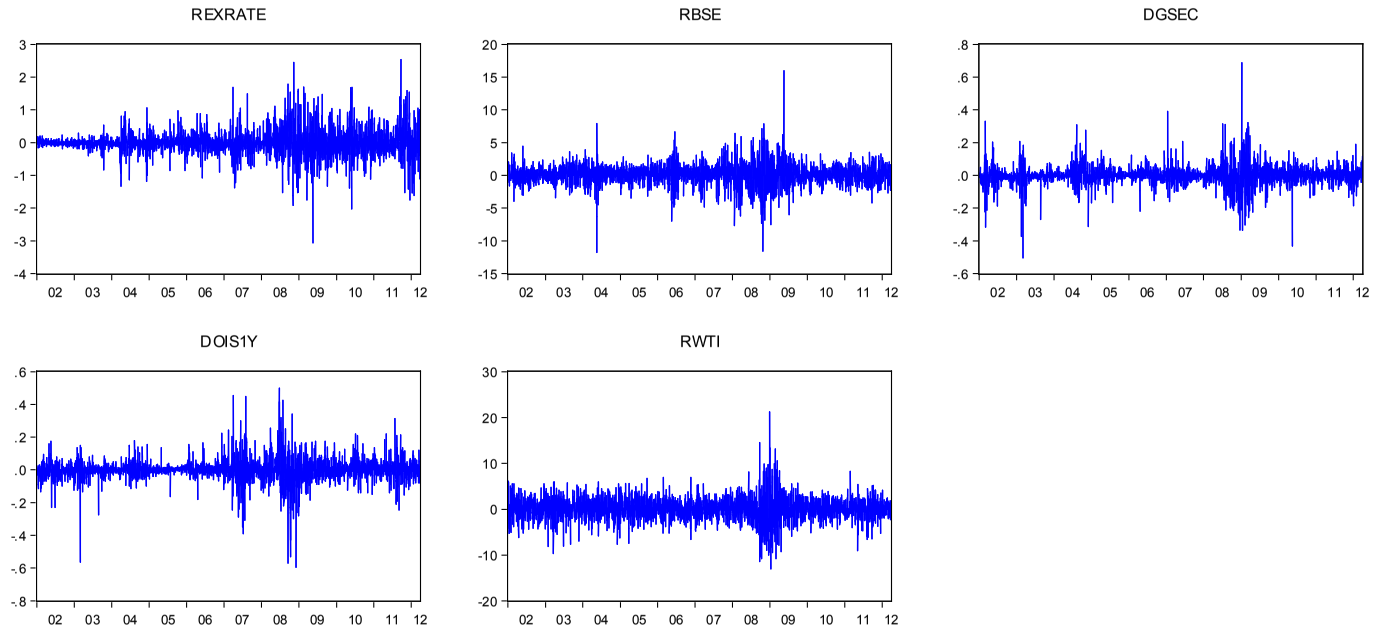

Figure 2: Returns and Differenced Variables

Note: Return Rupee-Dollar exchange rate (REXRATE), Return on Bombay Stock Exchange Index (RBSE), Differenced ten years benchmark yield (DGsec), Differenced one-year OIS rate (DOIS1Y) and Differenced Dollar-Index (USDX) and the return on international crude oil prices (WTI per barrel).

Table 2A: Pooled Volatility Estimate

(Estimation Period January 2003 to March 2012)

REXRATE	RBSE		CALL		DGSEC		SPD1		TEDSPD		DOIS1Y		FWD3M		RUSDX		RWTI	
	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.
Mean Equation																		
C(1)	-0.02	0.00	-0.01	0.03	-0.01	0.05	-0.02	0.02	-0.01	0.08	-0.01	0.06	-0.01	0.20	-0.01	0.03	-0.01	0.03
C(2)	0.11	0.00	4.74	0.00	0.0001	0.26	0.77	0.00	1.06	0.00	0.001	0.00	2.79	0.00	-0.02	0.06	0.08	0.06
Variance Equation																		
	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.
C(1,1)	0.0011	0.00	0.0013	0.00	0.0015	0.00	0.0012	0.00	0.0015	0.00	0.0013	0.00	0.0014	0.00	0.0014	0.00	0.0013	0.00
C(1,2)	-0.0035	0.00	-0.0003	0.51	0.00002	0.75	0.0002	0.48	0.0003	0.48	0.00001	0.23	-0.0065	0.00	0.0001	0.57	-0.0009	0.48
C(2,2)	0.0116	0.00	0.0111	0.00	0.00003	0.00	0.0012	0.00	0.0026	0.00	0.00003	0.00	0.1102	0.00	0.0008	0.08	0.1067	0.00
A1(1,1)	0.1028	0.00	0.1317	0.00	0.1454	0.00	0.1250	0.00	0.1482	0.00	0.1281	0.00	0.1380	0.00	0.1305	0.00	0.1221	0.00
A1(1,2)	0.0821	0.00	0.0457	0.00	0.0220	0.00	0.0497	0.02	0.0549	0.02	0.0335	0.00	0.0622	0.03	0.0094	0.08	0.0436	0.00
A1(2,2)	0.0655	0.00	0.6409	0.00	0.1280	0.00	0.8473	0.00	0.7379	0.00	0.0600	0.00	1.0448	0.00	0.0259	0.00	0.0155	0.00
D1(1,1)	0.0109	0.10	-0.0284	0.02	-0.0315	0.01	-0.0239	0.03	-0.0343	0.01	-0.0252	0.02	-0.0343	0.00	-0.0238	0.03	-0.0214	0.04
D1(1,2)	-0.0276	0.00	0.0152	0.46	0.0039	0.63	-0.0480	0.21	-0.0139	0.70	-0.0300	0.11	0.1008	0.02	0.0072	0.39	-0.0330	0.06
D1(2,2)	0.0698	0.00	-0.0725	0.19	-0.0575	0.00	0.0650	0.65	-0.0158	0.87	-0.0438	0.00	0.0400	0.76	0.0060	0.41	0.0610	0.00
B1(1,1)	0.8930	0.00	0.8758	0.00	0.8678	0.00	0.8843	0.00	0.8664	0.00	0.8809	0.00	0.8754	0.00	0.8768	0.00	0.8847	0.00
B1(1,2)	0.8983	0.00	0.8237	0.00	0.9622	0.00	0.7289	0.00	0.7043	0.00	0.9271	0.00	0.3430	0.00	0.9783	0.00	0.9078	0.00
B1(2,2)	0.9036	0.00	0.4455	0.00	0.8958	0.00	0.1654	0.00	0.2889	0.00	0.9623	0.00	-0.0135	0.00	0.9688	0.00	0.9315	0.00
E1(1,1)	0.0091	0.00	0.0125	0.00	0.0128	0.00	0.0102	0.00	0.0126	0.00	0.0111	0.00	0.0131	0.00	0.0123	0.00	0.0107	0.00
E1(1,2)	-0.0251	0.00	-0.0085	0.36	0.00007	0.70	-0.0131	0.13	0.0003	0.93	-0.0003	0.19	-0.0180	0.04	0.0008	0.37	-0.0254	0.04
E1(2,2)	0.0691	0.00	0.0327	0.47	0.0001	0.06	0.0037	0.46	0.0008	0.87	0.00004	0.01	-0.0815	0.00	-0.0004	0.78	0.0851	0.23

Note: Rupee-Dollar exchange rate (EXRATE/INRUSD), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1), Ted-Spread (difference between three-month MIBOR and the three-month T-bill interest rate, TEDSPD), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). Dollar-Index (USDX) and the international crude oil prices (WTI per barrel). The US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies.

Table 2B: Granger Causality Test for Volatility Spillover Across Different Markets

	Lags: 5			Lags: 4			Lags: 3		
Null Hypothesis:	Obs	F-Statistic	Prob.	Obs	F-Statistic	Prob.	Obs	F-Statistic	Prob.
HRBSE does not Granger Cause HREXRATE	2406.00	1.78	0.11	2407.00	2.07	0.08	2408.00	1.86	0.13
HREXRATE does not Granger Cause HRBSE		0.89	0.49		0.94	0.44		1.04	0.37
HCALL does not Granger Cause HREXRATE	2406	1.25	0.28	2407	0.66	0.62	2408	0.68	0.56
HREXRATE does not Granger Cause HCALL		2.44	0.03		3.16	0.01		4.24	0.01
HDGSEC does not Granger Cause HREXRATE	2406	2.49	0.03	2407	2.90	0.02	2408	2.71	0.04
HREXRATE does not Granger Cause HDGSEC		3.15	0.01		3.19	0.01		2.84	0.04
HSPD1 does not Granger Cause HREXRATE	2406	9.16	0.00	2407	10.68	0.00	2408	13.66	0.00
HREXRATE does not Granger Cause HSPD1		2.73	0.02		3.55	0.01		2.89	0.03
HTEDSPD does not Granger Cause HREXRATE	2406	2.03	0.07	2407	0.72	0.58	2408	0.67	0.57
HREXRATE does not Granger Cause HTEDSPD		1.92	0.09		2.44	0.04		2.43	0.06
HDOIS1Y does not Granger Cause HREXRATE	2406	3.27	0.01	2407	3.92	0.00	2408	4.81	0.00
HREXRATE does not Granger Cause HDOIS1Y		1.17	0.32		1.32	0.26		0.36	0.78
HFRW3M does not Granger Cause HREXRATE	2406	1.31	0.26	2407	0.91	0.46	2408	0.53	0.66
HREXRATE does not Granger Cause HFRW3M		2.88	0.01		3.59	0.01		1.14	0.33
HRDOLLARINDEX does not Granger Cause HREXRATE	2406	11.34	0.00	2407	9.06	0.00	2408	7.43	0.00
HREXRATE does not Granger Cause HRDOLLARINDEX		1.30	0.26		1.61	0.17		2.00	0.11
HRWTI does not Granger Cause HREXRATE	2406	2.24	0.05	2407	2.02	0.09	2408	1.77	0.15
HREXRATE does not Granger Cause HRWTI		1.31	0.26		1.42	0.23		1.29	0.27

H(Variable) is GARCH(1,1) estimate of conditional variance of the variable in the parentheses. For instance, HRExrate is GARCH(1,1) estimate of conditional variance of exchange rate return.

Table 3A: Pre-Crisis Volatility Estimate

(Estimation Period January 2003 to September 15, 2008)

REXRATE		RBSE		CALL		DGSEC		SPD1		TEDSPD		DOIS1Y		FWD3M		RUSDX		RWTI
	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.
Mean Equation																		
C(1)	-0.02	0.00	-0.01	0.10	-0.01	0.08	-0.01	0.06	-0.01	0.10	-0.01	0.07	-0.01	0.05	-0.01	0.19	-0.01	0.07
C(2)	0.15	0.00	4.74	0.00	-0.0004	0.77	0.78	0.00	0.73	0.00	0.001	0.09	1.57	0.00	-0.01	0.21	0.08	0.14
Variance Equation																		
	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.
C(1,1)	0.0028	0.00	0.0040	0.00	0.0031	0.00	0.0030	0.00	0.0030	0.00	0.0030	0.00	0.0030	0.00	0.0027	0.00	0.0030	0.00
C(1,2)	-0.0067	0.00	-0.0011	0.23	0.00001	0.45	0.0002	0.53	0.00004	0.94	0.0001	0.28	0.0009	0.66	0.0053	0.43	-0.0027	0.36
C(2,2)	0.0161	0.00	0.0109	0.00	0.00002	0.00	0.0013	0.00	0.0017	0.00	0.00002	0.00	0.0481	0.00	0.2974	0.00	0.5064	0.00
A1(1,1)	0.2051	0.00	0.3602	0.00	0.2829	0.00	0.2834	0.00	0.2879	0.00	0.2691	0.00	0.2829	0.00	0.1947	0.00	0.2846	0.00
A1(1,2)	0.1012	0.00	0.0772	0.04	0.0191	0.11	0.0777	0.04	0.0661	0.04	0.0395	0.16	0.1267	0.01	0.0533	0.36	-0.0155	0.50
A1(2,2)	0.0499	0.00	0.7607	0.00	0.1640	0.00	0.8287	0.00	0.5791	0.00	0.0807	0.00	0.8381	0.00	-0.0835	0.11	0.0008	0.74
D1(1,1)	0.0017	0.86	-0.1831	0.00	-0.1187	0.00	-0.1177	0.00	-0.1198	0.00	-0.1129	0.00	-0.1144	0.00	-0.0078	0.72	-0.1239	0.00
D1(1,2)	0.0128	0.73	0.0370	0.65	0.0025	0.82	-0.0543	0.28	-0.0301	0.55	-0.0504	0.36	-0.0728	0.43	0.0232	0.78	0.0265	0.53
D1(2,2)	0.0981	0.00	-0.1079	0.11	-0.1245	0.00	0.0738	0.66	-0.0177	0.86	-0.0646	0.00	-0.0778	0.62	-0.1138	0.02	0.0887	0.00
B1(1,1)	0.7883	0.00	0.7061	0.00	0.7682	0.00	0.7683	0.00	0.7652	0.00	0.7756	0.00	0.7668	0.00	0.7950	0.00	0.7690	0.00
B1(1,2)	0.8443	0.00	0.6021	0.00	0.9552	0.00	0.6794	0.00	0.7302	0.00	0.7876	0.00	0.4376	0.02	0.6887	0.05	0.8046	0.00
B1(2,2)	0.9043	0.00	0.3889	0.00	0.8931	0.00	0.1809	0.01	0.4293	0.00	0.9514	0.00	0.1813	0.00	0.4306	0.01	0.8418	0.00

Note: Rupee-Dollar exchange rate (EXRATE/INRUSD), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1), Ted-Spread (difference between three-month MIBOR and the three-month T-bill interest rate, TEDSPD), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). Dollar-Index (USDX) and the international crude oil prices (WTI per barrel). The US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies.

Table 4A: Post-Crisis Volatility Estimate
(Estimation Period November 2009 to March, 2012)

REXRATE		RBSE		CALL		DGSEC		SPD1		TEDSPD		DOIS1Y		FWD3M		RUSDX		RWTI
	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.
C(1)	-0.01	0.73	0.01	0.70	-0.01	0.67	-0.02	0.43	-0.01	0.69	-0.0014	0.93	-0.01	0.56	-0.01	0.19	0.00	0.83
C(2)	0.04	0.42	6.73	0.00	0.01	0.00	0.54	0.00	1.11	0.00	0.0049	0.03	5.45	0.00	-0.01	0.21	0.04	0.58
	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.	Coeff	Prob.
M(1,1)	0.0023	0.00	0.0042	0.04	0.0025	0.17	0.0038	0.06	0.0041	0.04	0.0029	0.12	0.0040	0.05	0.0027	0.00	0.0043	0.03
M(1,2)	-0.0138	0.00	-0.0009	0.60	-0.0002	0.09	-0.000	0.91	-0.0028	0.38	-0.0003	0.29	-0.0306	0.11	0.0053	0.43	-0.0199	0.01
M(2,2)	0.0850	0.00	0.0155	0.00	-0.000008	0.00	0.0011	0.06	0.0017	0.00	0.0001	0.01	0.0322	0.00	0.2974	0.00	0.2332	0.03
A1(1,1)	0.0608	0.00	0.0934	0.00	0.0897	0.00	0.0862	0.00	0.0899	0.00	0.0951	0.00	0.0840	0.00	0.1947	0.00	0.0893	0.00
A1(1,2)	0.0430	0.00	0.0329	0.28	0.0191	0.19	0.0305	0.35	-0.0014	0.98	0.0185	0.38	0.0502	0.37	0.0533	0.36	0.0180	0.31
A1(2,2)	0.0305	0.05	0.8404	0.00	0.0116	0.00	0.8543	0.04	0.6691	0.00	0.0418	0.00	1.1761	0.00	-0.0835	0.11	0.0036	0.61
D1(1,1)	0.0158	0.38	-0.0259	0.21	0.0022	0.93	-0.0117	0.63	-0.0197	0.37	-0.0108	0.64	-0.0118	0.60	-0.0078	0.72	-0.0171	0.40
D1(1,2)	-0.0368	0.10	0.0145	0.69	0.0330	0.25	-0.0583	0.49	-0.2664	0.09	-0.0181	0.74	-0.2898	0.02	0.0232	0.78	0.0047	0.95
D1(2,2)	0.0857	0.00	-0.1091	0.49	-0.0222	0.00	0.0609	0.88	-0.0110	0.94	-0.0167	0.21	-0.0615	0.84	-0.1138	0.02	0.0777	0.00
B1(1,1)	0.9252	0.00	0.9031	0.00	0.9047	0.00	0.9051	0.00	0.9034	0.00	0.9022	0.00	0.9059	0.00	0.7950	0.00	0.9024	0.00
B1(1,2)	0.8910	0.00	0.8387	0.00	0.9239	0.00	0.8551	0.00	-0.0153	0.98	0.9130	0.00	0.0387	0.93	0.6887	0.05	0.8960	0.00
B1(2,2)	0.8580	0.00	0.2820	0.00	1.0098	0.00	0.1340	0.49	0.3749	0.00	0.9330	0.00	-0.0503	0.44	0.4306	0.01	0.8896	0.00

Note: Rupee-Dollar exchange rate (EXRATE/INRUSD), the Bombay Stock Exchange Index (BSE), the overnight money market rate (Call), ten years benchmark yield (Gsec), the term spread (ten year Gsec yield minus one 364-day Tbill yield, SPD1), Ted-Spread (difference between three-month MIBOR and the three-month T-bill interest rate, TEDSPD), one year OIS rate (OIS1Y) and three month Rupee-Dollar forward premium (FWD3M). Dollar-Index (USDX) and the international crude oil prices (WTI per barrel). The US Dollar Index (USDX) is an index (or measure) of the value of the United States dollar relative to a basket of foreign currencies.

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