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Abstract

Since the adoption of a managed floating exchange rate system, the objective of the exchange rate policy in India is to curb excess volatility in the foreign exchange market through intervention operations by the RBI. The paper aims to analyse the effectiveness of the RBI intervention on the level and volatility of the rupee exchange rate with the U.S. $. The GARCH (1,1) model has been applied to the monthly data of exchange rate return and net intervention by the RBI from April 1993 to March 2013. The empirical results indicate that intervention does not affect the level of the rupee exchange rate. However, it is effective in containing the volatility of the exchange rate in the foreign exchange market though by a small magnitude. The volatility is persistent and has a long memory. The Granger causality test reveals that the past values of the exchange rate return indicate the possibility of future intervention by the RBI in the foreign exchange market.

Key Words: Exchange rate volatility, Intervention, GARCH, Granger causality

JEL Code(s): F 31, C 32

EXCHANGE RATE VOLATILITY AND EFFECTIVENESS OF INTERVENTION IN INDIA

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1. INTRODUCTION:

The exchange rate in India has undergone periods of stability and volatility since the adoption of a managed floating exchange rate. Recently, the rupee has remained under pressure due to either internal or external factors. It has triggered a concern among policy makers since the economic health of a country is showcased by the external value of its currency. Over a period, the exchange rate policy has evolved with gradual opening up of the current account in India.

Since March 1993 India has adopted a managed floating exchange rate regime without any pre-determined rate or band. The exchange rate policy is guided by the broad principles of careful monitoring and management of the exchange rates with flexibility, while allowing the underlying demand and supply conditions to determine its movement over a period in an orderly manner. Subject to this predominant objective, the RBI's intervention in the foreign exchange market is guided by the goals of reducing excess volatility, preventing the emergence of destabilizing speculative activities, maintaining adequate level of reserves and developing an orderly foreign exchange market (GOI, 2013, P. 140).

Intervention is defined as the official purchases or sales of foreign currencies that the monetary authorities of a country undertake with the objective of influencing future currency movements (Sahadevan, 2002, P. 2). There is a difference of opinion among economists regarding the effectiveness of intervention. Some believe that intervention does not affect either the level (leaning against the wind) or the volatility.

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Others hold the view that it influences the level of the exchange rate and can also calm or smooth disorderly market conditions whereas a sceptical group denies any impact of it on the exchange rate (Edison *et al.,* 2003).

Central Bank interventions are of two types *viz.,* non-sterilised and sterilized. The non-sterilized interventions change the monetary base and the interest rate structure in the country whereas with sterilised interventions the Central Bank undertakes an offsetting transaction through Open Market Operations to keep the monetary base and interest rates unchanged. Generally, intervention operations are sterilised to keep the money stock constant. Sterilised interventions affect the exchange rate through three main channels:

1. **Portfolio Balance Channel**: If the exchange rate is considered as the relative price of financial assets denominated in a number of foreign currencies and if domestic and foreign bonds are the imperfect substitutes then the sterilised intervention could affect the exchange rate. Any change in the reserve holdings of the Central Bank induces private participants to reshuffle their portfolio to balance exchange rate risk against the expected rate of return and, thus, the exchange rate changes (Sahadevan, 2002; Edison *et al.*, 2003).

2. **Signalling Channel**: If there is asymmetric information between market participants and the Central Bank then the expectations of market participants can be modified by the Central Bank regarding the future changes in its monetary policy stance. Intervention is an effective and predictable signal which can convey information about the future course of monetary policy actions. When the market revises its expectations of future money supplies, it also revises its expectations of the future spot exchange rate which brings about a change in the current rate (Sahadevan, 2002).

3. **Noise Trading Channel:** Noise traders are those whose demand for currencies or assets relies on the beliefs and sentiments which are inconsistent with economic fundamentals. Expectations regarding the future course of the exchange rate are based on its past behaviour. According to this channel, the Central Bank uses sterilized intervention to induce noise traders to buy or sell currency in the foreign

exchange market. The Central Bank can manipulate the exchange rate by entering in a relatively thin market so that the noise traders comprehend that the existing trend has been broken and, thus, the exchange rate is determined by the marginal demand and supply of the currencies in the foreign exchange market (Behera *et al*., 2008; Aguilar and Nydahl, 1998).

The RBI with its policy stance has intervened periodically in the international foreign exchange market to maintain the exchange rate at the desired levels. Therefore, the objective of the paper is two-fold,

1. To econometrically measure the level and volatility of the rupee exchange rate.
2. To analyse the effectiveness of the RBI interventions *i.e.,* how far the RBI has succeeded in curbing the volatility through its intervention operations.

The rest of the paper is organised as follows. Section Two highlights the existing literature. Section Three explains the data and methodology and the empirical results are enlisted in its sub-section. The last Section draws the main conclusions.

2. LITERATURE BACKGROUND:

Against the backdrop of numerous crises, fluctuations in the exchange rate of currencies have propelled voluminous research in recent times. There are three different opinions with regard to the effectiveness of intervention in the literature. Firstly, intervention curbs exchange rate volatility; secondly, intervention increases uncertainty and, thus, aggravates the volatility of the exchange rate and thirdly, intervention is ineffective in reducing the volatility.

The first view was supported by many authors. Kim *et al.* (2000) studied the effect of intervention by the Reserve Bank of Australia and using an EGARCH model found a positive correlation between the intervention and the exchange rate return indicating that interventions reduced the exchange rate volatility. Studies pertaining to Japan undertaken by Ramaswamy and Samiei (2000), Hoshikawa (2008) applying GARCH and Ito (2002) using regression supported this view. They suggested that co-ordinated and high frequency interventions have curbed the volatility in Japan.

Hillebrand and Schnabl (2004) found contradictory results for two sub-periods in their study. The GARCH analysis revealed that interventions aggravated volatility in the former period whereas the latter period confirmed the inhibition of volatility in Japan. Similar results were obtained by Kamil (2008) in his study on Colombia. In contrast to the above literature the studies undertaken in the case of the U.S., Japan, Germany, Australia and Zambia, using GARCH analysis detected that the intervention operations conducted by the Central Banks have actually increased volatility in their respective currencies (Baillie and Osterberg, 1997; Dominguez, 1993, 1998; Doroodian and Caporale, 2001; Edison *et al.*, 2003; Mwansa, 2009).

Curbing the excessive rupee volatility through intervention being the prime objective of the exchange rate policy of the RBI, recently many authors have sought to analyse the effectiveness of the RBI intervention on the rupee exchange rate in the FOREX market. Even in the case of India two contradictory views prevail in the empirical literature. Pattanaik and Sahoo (2001) assessed the effectiveness of intervention operations by applying the OLS and 2-SLS regression method and found little evidence of the potency of intervention in influencing the volatility of the rupee exchange rate. Using the GARCH model, Unnikrishnan and Mohan (2001), Behera *et al.* (2008) and Goyal *et al*. (2009) studied the effectiveness of the RBI intervention on the rupee-U.S. $ exchange rate. The former two studies revealed that the RBI intervention has been effective in containing the volatility but not the level of the exchange rate in the market whereas Goyal *et al.* (2009) found the effect on the level as well as on the volatility. Goyal and Arora (2012) and Inoue (2012) employed the EGARCH model to infer that the intervention is the most effective instrument in the hands of the Central Banks in dampening the volatility. On the other hand, the ineffectiveness of intervention was detected by some of the studies. They stated that the RBI intervention is ineffective in changing the exchange rate trends as well as did not have any stabilizing effect on it (Bhaumik and Mukhopadhyay, 2000; Sahadevan, 2002). Attempts have also been made to analyse the effectiveness by applying variants of the GARCH models by Vadivel (2009, 2011) and Vadivel and Ramachandran (2013). All these studies emphasized that the intervention operations of the RBI did not wield any effect on the rupee exchange rate in India.

The existing literature on India has not cleared the air regarding the effect of RBI intervention. Given the ambiguity about the impact of intervention on the rupee exchange rate, this paper analyses the effectiveness of intervention of the RBI in India since the adoption of a managed floating exchange rate. The period since April 1993 constitutes a large sample as required by the ARCH/GARCH models. It is aimed at assessing the sole effect of intervention on the exchange rate of the rupee which has not been attempted for India. The study covers the period which has been a testing time for the RBI since the eruption of the global financial crisis. This study hopes to clear the diversity in views regarding the effectiveness of intervention to some extent in the case of India.

3. EMPIRICAL EVIDENCE:

The empirical analysis will be presented in the following two sub-sections. The first sub-section will explain the variables, data sources, sample period and the methodology adopted for the study. The results from the model will be exhibited in the next sub-section.

3.1 Data Coverage and Methodological Approach:

The rupee exchange rate volatility and the effectiveness of the RBI intervention in the foreign exchange market has been analysed using the exchange rate return and net intervention (INV) by the RBI in the foreign exchange market. The period since liberalisation has been chosen for analysing the effect of intervention on the exchange rate level and volatility. Therefore, the data ranges from April 1993 to March 2013 for the exchange rate return and intervention comprising of 240 observations. Monthly data is used for the analysis because the RBI publishes the net intervention data only on a monthly basis though it intervenes daily, periodically, or rather, on a minute-by-minute basis in the foreign exchange market. The exchange rate return has been calculated as the percentage difference between the log exchange rate of the current and previous period as

$$\text{Return} = (\ln S_t - \ln S_{t-1})x100 \qquad \text{......................} \quad (1)$$

where, S is the nominal exchange rate of the rupee per U.S. $. The intervention is net purchases or sales of the U.S. $ (million) by the RBI in the foreign exchange market. The source of the data is Handbook of Statistics on the Indian Economy, the RBI Bulletins and International Financial Statistics of the IMF (IMF, 2013; RBI, 2013a; 2013b).

The exchange rate return and INV are plotted in Figure 1. In the figure, the return series indicates volatility clustering as large changes in returns are followed by other series of large changes and small changes are often followed by small changes. It implies that volatility shocks at the current period will influence the expectation of volatility many periods in the future. The net intervention series depicts that with higher fluctuations in the return the intervention by the RBI is also of a greater magnitude. Whenever the returns are positive, indicating depreciation of the rupee, the RBI has sold the U.S. $ to absorb excess currency flow in the market whereas the negative returns have led to the purchase of the U.S. $ by the RBI.

The ARCH family of models are designed to capture such volatility clustering and heteroskedastic nature of the financial time series data. Engle (1982) proposed an Auto Regressive Conditional Heteroskedastic (ARCH) model for modelling volatility and changes in it over time. Bollerslev (1986) extended Engle's work and developed a

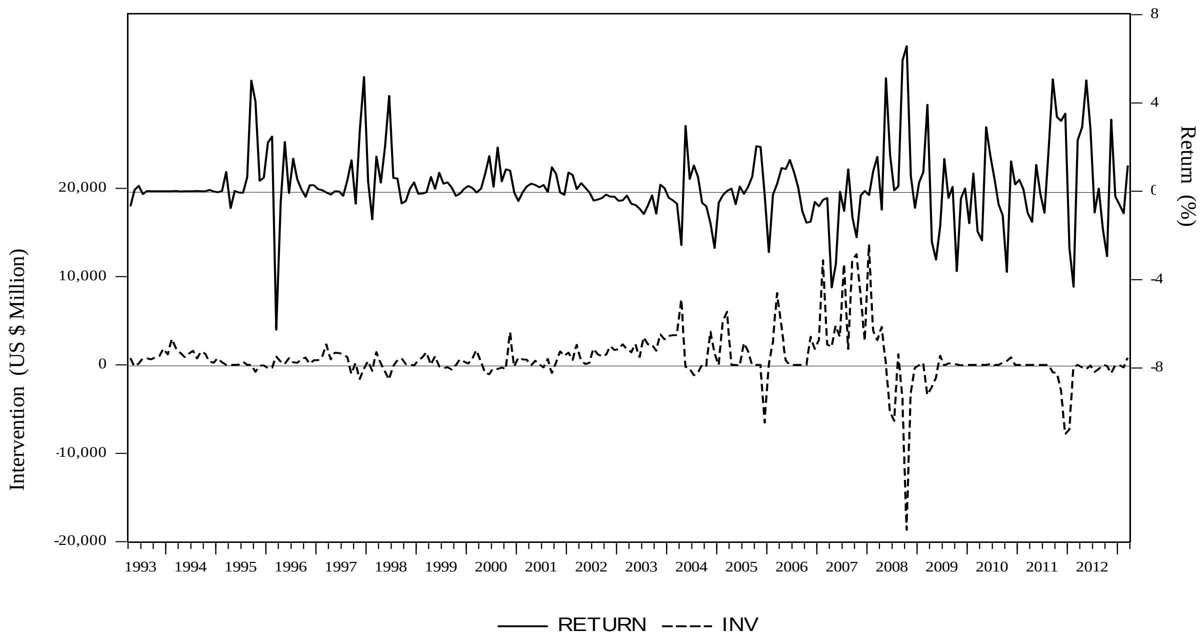

Figure 1: Exchange Rate Return and INV from April 1993 to March 2013

generalised ARCH (GARCH) model to capture volatility aspects in financial time series. GARCH is more parsimonious than ARCH. It captures complicated patterns of time variability in the conditional variance using fewer parameters than ARCH model and the likelihood function provides a systematic way to adjust the parameters to give the best fit (Mehdi *et al.*, 2012). The GARCH model covers most of the information about the exchange rate behaviour and captures the volatility clustering in the exchange rate data. The model allows testing the effect of intervention on the level and volatility of the exchange rate simultaneously in the mean and variance equation respectively. In a GARCH model, the error variance is assumed to follow an ARMA process which means it allows for autoregressive and moving average components in the heteroskedastic variance.

Suppose GARCH (p, q) is given as

$$\Delta \ln e_t = \mu + \delta_i \sum_{i=1}^{p} \Delta \ln e_{t-i} + \lambda_i INV_{it} + \varepsilon_t \qquad \text{.........................} \quad (2)$$

where,

$$\varepsilon_t = \sqrt{h_t} \quad \text{and} \quad \varepsilon_t \mid \Omega_{t-1} \approx N(0, h_t)$$

$$h_t = \omega + \alpha_i \sum_{i=1}^{q} \varepsilon_{t-i}^2 + \beta_j \sum_{j=1}^{p} h_{t-j} + \phi_i INV_{it} \qquad \text{.........................} \quad (3)$$

where, p is the order of a GARCH term and q is the order of the ARCH term. Intervention (INV) is the exogenous variable in the GARCH process.

Based on the Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC) criterion, the GARCH (1,1) is chosen as the parsimonious model to analyse the volatility of the exchange rate return and the effect of intervention on the level and volatility of the return in India as follows,

$$\text{Return} = \mu + \lambda \; INV_t + \varepsilon_t \qquad \text{.........................} \quad (4)$$

where,

$$\varepsilon_t = \sqrt{h_t} \quad \text{and} \quad \varepsilon_t \mid \Omega_{t-1} \approx N(0, h_t)$$

$$h_t = \omega + \alpha \; \varepsilon_{t-1}^2 + \beta \; h_{t-1} + \phi \; INV_t \qquad \text{.........................} \quad (5)$$

where α, $\beta > 0$, μ and ω are the constant terms. Return is the exchange rate return of the rupee per U.S. $. INV is the net intervention variable. The disturbance term ε_t is assumed to follow a normal distribution conditional on the information set Ω available to the participants in the foreign exchange market at the time t-1 with zero mean and variance h_t. Conditional variance h_t allows for the possibility of time-varying and clustering conditional volatility. ε^2_{t-1} and h_{t-1} are the ARCH and GARCH terms respectively. Equation (4) is the mean equation and it measures the effect of intervention on the level of exchange rate. The variance equation is defined in equation (5) which captures the effect of the intervention on the volatility of the rupee. The coefficient of intervention measures the percentage change in the exchange rate of the rupee for the purchase of U.S. $ 1 million. Hence, according to the theory, in the variance equation, α is expected to bear a positive sign if the intervention alters the level of exchange rate and β should possess a negative sign for the intervention to be effective in curbing the volatility of the exchange rate in the market.

The degree of volatility persistence is measured via a Wald test. The null hypothesis suggests that the sum of α and β is equal to one against the alternative less than one. The rejection of the null hypothesis connotes stationarity of the error variance. It implies that if the sum of α and β is significantly less than one then the volatility is persistent and has a long memory but it is still mean reverting. The Granger causality test for the causal relationship between the return and intervention will also be conducted. The selected model has been estimated using E-VIEWS 7.1 version of the software.

3.2 Empirical Results:

The literature on exchange rates in the international financial arena suggests that it follows a martingale heteroskedastic process. Before estimating the GARCH model it is a prerequisite to check for a unit root and conduct the other diagnostic tests to confirm the adequacy of the chosen model.

The Augmented Dickey-Fuller (ADF) and Phillips Perron unit root tests have been calculated with the null hypothesis that the series contains a unit root or is nonstationary. Both these tests confirm that the return and INV are stationary at level by rejecting the null hypothesis at 1 percent level of significance (Table 1). Alternatively, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with the null hypothesis of the variable being stationary has been computed and results are presented in Table 2. The test statistic confirms the non-rejection of the null hypothesis again at 1 percent level of significance implying that both variables are stationary.

Table 1: Unit Root Tests

Test	**Return**		**INV**	
Null: Unit Root Present	**t-Statistic**	**P-value**	**t-Statistic**	**P-value**
Augmented Dickey-Fuller	- 11.21	0.00	- 4.85	0.00
Phillips-Perron	- 11.07	0.00	- 9.68	0.00

Table 2: KPSS Test

Test	**Return (LM-Statistic)**	**INV (LM-Statistic)**	**5% critical value**
Null: Variable is Stationary			
KPSS test	0.11	0.13	0.46

The descriptive statistics of the exchange rate return indicates that the return is positively skewed and is leptokurtic in nature as the kurtosis is 6.46 (Table 3). This highlights the presence of volatility in the exchange rate return. Using the Jarque-Bera test, the test of normal distribution, it is deduced that the return follows a non-normal distribution as the null hypothesis of normal distribution is rejected with zero probability.

Table 3: Descriptive Statistics of Return and Intervention (INV)

Variable	**Return**	**INV**
Mean	0.23	709.46
Median	0.01	239.04
Maximum	6.57	13625.00
Minimum	- 6.27	- 18666.00
Std. Dev.	1.63	2811.42
Skewness	0.57	- 0.04
Kurtosis	6.46	17.48
Jarque-Bera	132.89 (0.00)	2096.04 (0.00)
Observations	240	240

The diagnostic tests of Ljung-Box Q statistic and the Lagrange Multiplier (LM) test of ARCH effects are carried out to detect the presence of heteroskedaticity in the return series. The Ljung-Box test statistic checks for the autocorrelation in the residuals and squared residuals whereas the LM test of ARCH traces for any ARCH or GARCH effects in the variable. To conduct these tests, the mean equation is estimated using the OLS method. The Ljung-Box Q statistic for residuals and squared residuals confirms the autocorrelation in residuals upto lag length 10 (Table 4). It can be alternatively interpreted that residuals have ARCH effects. The LM test reinstates the presence of ARCH effects in return as the null hypothesis of no ARCH effects is rejected at 1 percent level of significance. These tests affirm the appropriateness of the GARCH model for analysing the exchange rate return series.

Table 4: Ljung-Box Q Statistic and LM Test Statistic of ARCH Effects

Lag Length	Residuals		Squared Residuals		LM Stats	
	Q-Stat	Probability	Q-Stat	Probability	$N.R^2$	Probability
1	17.388	0.000	10.703	0.001	10.532	0.001
2	21.730	0.000	11.842	0.003	10.597	0.005
3	24.576	0.000	12.523	0.006	10.768	0.013
4	25.832	0.000	20.647	0.000	17.215	0.002
5	25.851	0.000	31.190	0.000	21.661	0.001
6	31.541	0.000	45.074	0.000	28.113	0.000
7	32.043	0.000	45.992	0.000	28.003	0.000
8	33.031	0.000	47.381	0.000	27.967	0.001
9	33.246	0.000	47.383	0.000	29.221	0.001
10	33.246	0.000	47.394	0.000	30.786	0.001

As the distribution of return is non-normal, the GARCH model is estimated using the Student's t-distribution by maximising the log likelihood function through an iterative process. The BHHH algorithm developed by Berndt *et al.* (1974) is used as it gives more stable and robust results compared to Marquardt algorithms (Goyal and Arora, 2010). Based on the selected GARCH (1,1) model, the mean and variance equation are estimated and results have been presented in Table 5. The coefficient of intervention in the mean equation is significant. However, the sign is the opposite of the expected relationship. It implies that the RBI's intervention does not alter the level of the exchange rate in the international financial market. Nevertheless, the INV variable is highly significant and negative as expected in the variance equation. The coefficient is (-) 0.00009 of the intervention which means that the purchase of U.S. $ 100 million reduces the volatility by 0.9 percent. Therefore, it could be inferred that

Table 5: Results of GARCH (1, 1) Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation: Return = $\mu + \lambda \ INV_t + \varepsilon_t$				
μ	0.36014	0.15003	2.40038	0.01640
INV	- 0.00022	0.00003	- 6.64624	0.00000
Variance Equation: $h_t = \omega + \alpha \ \varepsilon^2_{t-1} + \beta \ h_{t-1} + \phi \ INV_t$				
ω	0.65953	0.24461	2.69628	0.00700
α	0.10603	0.05165	2.05269	0.04010
β	0.73228	0.09417	7.77610	0.00000
INV	- 0.00009	0.00002	- 5.37929	0.00000
R^2	0.12	Durbin-Watson	1.46	
Adjusted R^2	0.11	AIC	4.02	
Log likelihood	-475.88	SIC	4.13	
Wald Stats	3.98 (0.04)			

Note: Figure in parenthesis indicates the probability.

the intervention actions undertaken by the RBI have curbed the rupee volatility in the market though the magnitude of volatility reduction is very marginal. The null hypothesis of the Wald test is rejected indicting that coefficients are significant. The sum of the ARCH term (α) and GARCH term (β) in the variance equation is 0.84 (0.11+0.73) meaning that the volatility is persistent and has a long memory. Since the sum is less than unity it also implies that the return will not take much time to revert back to its mean value.

After modelling the return it is customary to check for the remaining autocorrelation in residuals or ARCH effects in the model. The results of the Ljung-Box Q statistic for standardised residuals and squared residuals confirm that there do not remain any autocorrelation effects in the modelled return series. Similarly, the LM test of ARCH effects does not reject the null hypothesis of no ARCH effects (Table 6). This reasserts that the heteroskedasticity in the return series has been modelled appropriately.

The conditional volatility of returns over the period estimated by the GARCH model has been presented in Figure 2. After the introduction of a market-determined exchange rate system, the exchange rate of the rupee was quite stable until the outbreak of the Mexican Crisis and the East Asian Crisis in the second half of the 1990s. During these periods the rupee exchange rate exhibited high volatility due to

Table 6: Ljung-Box Q statistic and LM test Statistic of Standardised Residuals

Lag Length	Residuals		Squared Residuals		LM Stats	
	Q-Stat	Probability	Q-Stat	Probability	$N.R^2$	Probability
1	3.620	0.057	0.001	0.971	0.001	0.972
2	5.522	0.063	0.012	0.994	0.011	0.994
3	5.527	0.137	0.024	0.999	0.023	0.999
4	10.536	0.032	0.164	0.997	0.156	0.997
5	10.590	0.060	0.173	0.999	0.164	0.999
6	11.024	0.088	0.177	1.000	0.168	0.999
7	11.050	0.136	0.190	1.000	0.177	1.000
8	11.511	0.174	0.211	1.000	0.193	1.000
9	12.972	0.164	0.284	1.000	0.262	1.000
10	13.027	0.222	0.298	1.000	0.273	1.000

sudden and sharp reversal of the market sentiments and expectations. Post these crises, the Indian foreign exchange market remained tranquil as reflected in the lower volatility of the rupee exchange rate. The global financial crisis again exerted a downward pressure on the rupee in 2008 after which it has not gained the stability as clearly reflected in the higher volatility of the return.

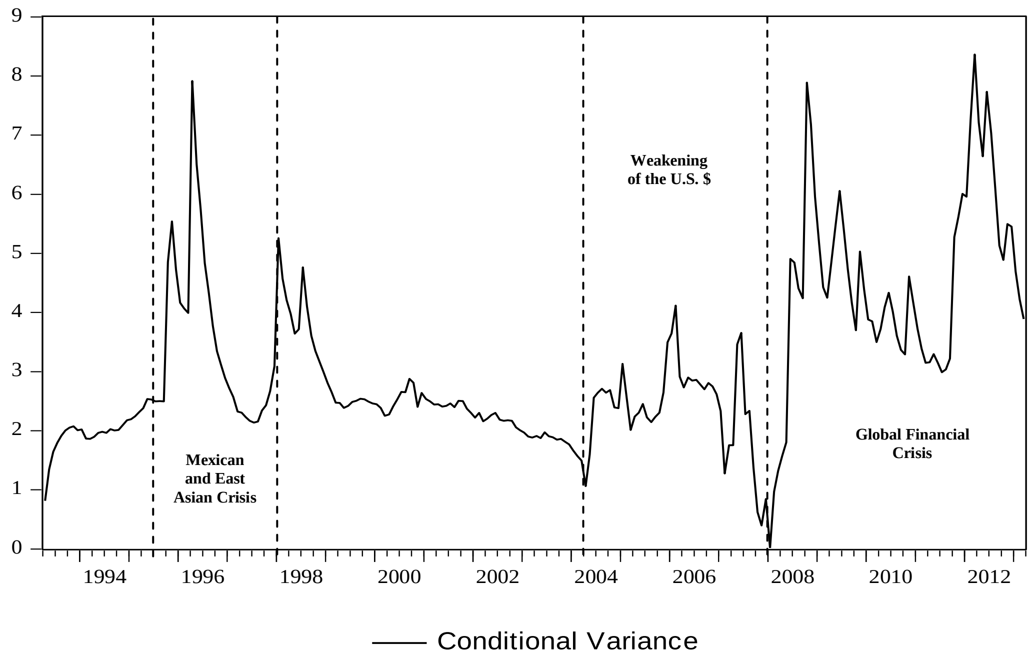

Figure 2: Estimated Conditional Volatility of the Return

Further, results of the Granger causality test indicate one-way causality from the return to intervention (Table 7). The null hypothesis of intervention not Granger causing return has not been rejected at 95 percent confidence level whereas the null hypothesis of return not Granger causing intervention has been rejected at 5 percent

Table 7: Pair-wise Granger Causality Test Results

Null Hypothesis:	Observations	F-Statistic	Probability.
INV does not Granger Cause RETURN	239	2.74130	0.0991
RETURN does not Granger Cause INV		14.6921	0.0002

level of significance implying that the return has Granger caused intervention. It means that the past values of return helped predict the future intervention by the RBI in the international foreign exchange market.

4. CONCLUSIONS:

The RBI acts as a watchdog on the rupee exchange rate fluctuations and, thus, resorts to intervention in the foreign exchange market whenever the rupee is under pressure to curtail the volatile nature of the exchange rate reflecting the commitment to a market-determined exchange rate system. The effectiveness of such intervention has been analysed using the GARCH (1,1) model. The estimation of the GARCH (1,1) exhibits that, in India, intervention does not affect the level of the exchange rate. However, it has successfully curbed the volatility in the exchange rate of the rupee although by a small magnitude. Nevertheless, the volatility is persistent and has a long memory. The Granger causality test results infer that intervention depends on the past values of return and, thus, intervention takes place on the basis of changes in the return. It reinstates the inclination of the RBI to undertake intervention whenever the market is in a disorderly condition. The results obtained by this study are in concordance with the results stated by Behera *et al*. (2008) and supports the view that intervention reduces volatility of the exchange rate in India. The available data frequency of the net intervention undertaken by the RBI, however, limits the analysis of the effectiveness of the RBI intervention as the volatility models perform better with high frequency data.

Over the period, intervention by the RBI has served as a powerful instrument for the management of the exchange rate. However, the effect on the volatility is miniscule. Policy makers cannot overlook this aspect as recently India has undergone series of external crisis and the RBI has been unsuccessful in sweeping away the turmoil in the foreign exchange market. India experienced tremendous downward pressure on the exchange rate of the rupee especially after the global financial crisis. In such a situation, policy makers are expected to explore more ways of effectively handling the rupee volatility in the international market. Rather than exhausting the foreign exchange reserves the impact of alternative instruments such as news, communication should be studied and analysed as suggested by Goyal and Arora (2010). Publically announced interventions are found to have larger impact on the volatility rather than secret interventions. Thus, if the future intervention actions are publically declared prior to the intervention operation then the market expectations would play a prominent role in shifting the exchange rate to a desired level before the actual intervention in the market. Also, in order to make the economy resilient at the international level, internal factors must be maintained at the desirable levels. This could build the confidence among the investors and speculators about the Indian economy which would then be reflected in a stronger external value of the rupee in the future.

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