Chapter 4

Does Exchange Rate Intervention Contain Exchange Rate Volatility?

4.1 Introduction

In the previous chapters, the study has focused on factors responsible for large stockpile of reserves and on the changing nature of intervention policy over time depending upon the foreign exchange market condition. Though this exercise is extremely useful to understand the reason for accumulation of reserves and characteristics of intervention policy, they do not completely address the issues revolving around the exchange rate management policy of the RBI. The intervention policy in India is specifically designed to ensure orderly conditions in the foreign exchange market, because the foreign exchange market in India is not yet very deep and broad and is characterized by uneven flows of demand and supply over different periods. The market is dominated by few major players and characterized by lumpy public sector demands that largely reflect oil imports and servicing of external debt etc. This can lead to adverse expectations, which tend to be self-fulfilling in nature, given their effect on “leads and lags” in payments and receipts. Growing supply-demand mismatch and inter-bank activity to take advantage of such mismatch can trigger volatility, which may not be in tune with the fundamentals (Report on Currency and Finance, 2003-04; Para 4.64).

As far as the foreign exchange rate management is concerned, the prime objective of the RBI has been to ensure realistic and credible external value of rupee and to ensure adequate stock of foreign exchange reserves for stabilize exchange rate. While describing the characteristics of exchange rate intervention policy the former governor of the RBI Bimal Jalan stated that
“the Reserve Bank has been prepared to make sales and purchases of foreign currency in order to even out lumpy demand and supply in the relatively thin forex market and to smoothen jerky movements. However, such intervention is not governed by a predetermined target or band around the exchange rate” (Jalan, 1999).

He further made it clear that “the broad principles that have guided India after the Asian crisis of 1997 are: (i) careful monitoring and management of the exchange rate without a fixed or pre-announced target or a band; (ii) flexibility in the exchange rate together with ability to intervene, if and when necessary; (iii) a policy to build a higher level of foreign exchange reserves which takes into account not only anticipated current account deficits but also ‘liquidity at risk’ arising from unanticipated capital movements; and (iv) a judicious management of the capital account” (Jalan, 2002).

The official statements regarding the intervention policy exemplify the fact that intervention is principally meant for managing volatility with no fixed rate target while allowing the market forces to determine the exchange rate. Therefore, this chapter deals with the crucial question as to whether intervention has impacted exchange rate and its volatility in the desired direction. Although empirical studies dealing with this issue have come out with mixed results, one important aspects of official intervention seems to indicate that there is asymmetric response of the authority to appreciating and depreciating domestic currency.

Edison (1993) provides empirical evidence to show that central bank response to exchange rate changes is asymmetric in the sense that exchange rate appreciation is, often, penalized more severely than exchange rate depreciation of the same magnitude. The central banks prefer such asymmetric intervention, as they seem to believe that appreciation of domestic currency tends to affect export competitiveness (Dooley, Folkerts-Landau and Garber, 2003).
In other words, exchange rate intervention policy is often triggered by the concern about export growth. Such asymmetry has also been established in the Indian context by Ramachandran and Srinivasan (2007). This study further documents evidence to show that asymmetry has been the major cause for accumulation of foreign exchange reserves i.e. the RBI has been relatively more aggressive in preventing rupee appreciation. Against these backdrops, this chapter examines whether the RBI’s intervention could reduce the volatility. While doing so, we also examine whether intervention has asymmetric impact on exchange rate and on its volatility.

4.2 Why A-PARCH model?

There are plenty of empirical studies that apply some version of ARCH and GARCH models to examine the impact of intervention on exchange rate volatility. The reason behind application of such model is that high frequency data exhibit unconditional leptokurtosis. In this respect, studies by Westerfield (1997) and Hsieh (1988) found presence of temporal clustering in variance of exchange rate changes. Hence, there are number of empirical studies that apply autoregressive conditional heteroskedasticity models (ARCH) of Engle (1982) and generalized autoregressive conditional heteroskedasticity models (GARCH) of Bollerslev (1986) and provide evidence to show that prediction errors of exchange rate changes exhibit clusters.

In addition, the response of financial market volatility to positive and negative shocks is not often found to be symmetric. Nelson (1991) argues that frequency at which data are sampled becomes very high, persistence should become larger. Both unexpected positive and negative excess returns on stocks changes the next period's conditional volatility of the excess return on stocks. Unexpected positive returns result in a downward revision while unexpected negative returns result in an upward revision. Indeed, Nelson (1991) and Engle and Ng
(1993) found different effects for positive and negative unexpected returns, but both led to variance increases.

However, Engle (1982) type ARCH model and Bollerslev (1986) type GARCH model define variance of a variable as conditional on its past prediction errors. Such approach imposes the restriction on the power of explanatory variable in the variance equation to be 2 which may not be appropriate under certain circumstances. For instance, if correlation between absolute return on holding foreign exchange is substantially more than the correlation between return themselves or between the square of the return then the usual ARCH/GARCH modeling of exchange rate return is not appropriate. In this context, Taylor (1986) and Schwert (1990) define conditional standard deviation as a function of lagged absolute returns (residuals). Taylor (1986) found that the absolute stock return has higher serial correlation over long lags i.e. the absolute return has long memory than their squared terms.

Ding et.al. (1993) investigated autocorrelation structure on return series of S&P 500 stock market and found that absolute return has high serial correlation than return themselves. The evidence from this study indicate that one can characterize \(|r_t|^d\) to be long memory and this property of the return series is very strong when \(d = 1\). Tse and Tsui (1997) found that the absolute return on Singapore dollar/US Dollar exchange rate has high correlation than the return. Therefore, we examine the long memory property of the return on exchange rate, its absolute value and square of it before modeling the exchange rate return and its volatility. Nonetheless, Ding et. al. (1993) questioned that “why should assume the conditional variance is a linear function of lagged squared returns as in Bollerselev’s GARCH, or the conditional standard deviation a linear function of lagged absolute returns as in Taylor/Schwert model”. They provide a general class of model wherein five other ARCH/GARCH type models can be nested. The general structure is:
\[ e_i = s_i e_i \quad \text{and} \quad e_i \approx N(0, 1) \] (4.1)

\[ s_i^\delta = \alpha_0 + \sum_{i=1}^{p} \alpha_i (|e_{i-1}| - \gamma_i e_{i-1})^\delta + \sum_{j=1}^{q} \beta_j s_{i-j}^\delta \]

where

\[ \alpha_0 > 0, \quad \delta \geq 0 \]
\[ \alpha_i \geq 0, \quad i = 1, ..., p \]
\[ -1 < \gamma_i < 1, \quad i = 1, ..., p \]
\[ \beta_j \geq 0, \quad j = 1, ..., q \]

The asymmetric response of volatility to positive and negative shocks in return is measured by \( \sum \alpha_i \). If the coefficient is positive and significant then response of standard deviation of return to appreciating rupee is much stronger than to depreciating rupee. This is well known as leverage effect in the finance literature in the sense that volatility in the stock market tend to rise in response to bad news and fall in response to good news. For the purpose of present study, we use equation (4.1) as a base to examine the response of exchange rate volatility to official intervention in the foreign exchange market.

### 4.3 The empirical results

The exchange rate equation is estimated using weekly data for the sample period from 06 October 1996 to 25 March 2011. We begin with presenting the autocorrelation structure for weekly return on Re/US$ exchange rate (\( \hat{e}_i \)), \( |\hat{e}_i| \) and for \( \hat{e}_i^2 \) in Table 4.1 and plot the same in Fig. 4.1. The serial correlation is calculated for all three variables under consideration upto 100 lags. It is very clear from the Table that the absolute return (\( |\hat{e}_i| \)) has high correlation than the other two measures, which is consistent with the findings of earlier studies [Karanasos and Kim (2006); French et al. (1986); Poterba & Summers (1988); and Ding
Thus, the estimates of serial correlation provide ample support to use A-PARCH specification to model return on foreign exchange and its volatility.

Table 4.1: Autocorrelation of $\hat{\epsilon}_t$, $|\hat{\epsilon}_t|$ and $\hat{\epsilon}_t^2$

<table>
<thead>
<tr>
<th>Data</th>
<th>Lags 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>40</th>
<th>70</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\epsilon}_t$</td>
<td>0.033</td>
<td>0.114</td>
<td>0.018</td>
<td>0.008</td>
<td>0.058</td>
<td>-0.018</td>
<td>0.076</td>
<td>0.004</td>
<td>0.012</td>
<td>-0.007</td>
</tr>
<tr>
<td>$</td>
<td>\hat{\epsilon}_t</td>
<td>$</td>
<td>0.340</td>
<td>0.308</td>
<td>0.242</td>
<td>0.295</td>
<td>0.241</td>
<td>0.235</td>
<td>0.223</td>
<td>0.134</td>
</tr>
<tr>
<td>$\hat{\epsilon}_t^2$</td>
<td>0.215</td>
<td>0.184</td>
<td>0.096</td>
<td>0.167</td>
<td>0.157</td>
<td>0.139</td>
<td>0.164</td>
<td>0.042</td>
<td>0.040</td>
<td>0.021</td>
</tr>
</tbody>
</table>

Fig. 4.1: Autocorrelation of $|\hat{\epsilon}_t|$, $\hat{\epsilon}_t^2$, and $\hat{\epsilon}_t$

For the sake of comparison, we present the empirical estimates of both GARCH and A-PARCH models. The RBI intervention is measured as percentage change in foreign currency assets. The other components of foreign reserves such as Gold, SDR and IMF tranch positions are not considered as they constitute negligible proportion of foreign reserves and not used for intervention purpose. Before estimating equation (4.1), the stationary properties of both percentage change in foreign currency assets and in exchange rate are examined using
the Augmented Dickey-Fuller test (ADF) and Phillips-Perron unit root test. The results of unit root tests produced in Table 4.2 show that the null hypothesis of unit root can be rejected at conventional significance level; suggesting that they are stationary stochastic process.

Table 4.2. Unit root test

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADF</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \hat{\varepsilon}_t )</td>
<td>-16.862 (0.00)</td>
<td>-26.633 (0.00)</td>
</tr>
<tr>
<td>( \tilde{R}_t )</td>
<td>-13.115 (0.00)</td>
<td>-19.351 (0.00)</td>
</tr>
</tbody>
</table>

p values are given in parentheses.

First we apply GARCH specification to model percentage change in foreign exchange since it is more parsimonious. After an extensive search with the help of relevant diagnostic statistics we arrive at the estimates of the following GARCH (1, 2) model for exchange rate return.

\[
\hat{\varepsilon}_t = 0.057 - 0.010 \hat{R}_t + \varepsilon_t \\
(0.00) (0.00)
\]

\[
\sigma_t^2 = -5.487 + 0.160 \varepsilon_{t-1}^2 + 0.600 \sigma_{t-1}^2 + 0.239 \sigma_{t-2}^2 + 0.693 | \hat{R}_t | \\
(0.00) (0.00) (0.00) (0.46) (0.00)
\]

ARCH-LM (4) 1.233 (0.87) Log likelihood -653.96

\[
\hat{\varepsilon}_t = 0.027 - 0.185 \hat{R}_t^s - 0.064 \hat{R}_t^b + \sqrt{\sigma_t^2} \nu_t \\
(0.24) (0.00) (0.04)
\]

\[
\sigma_t^2 = -5.421 + 0.159 \varepsilon_{t-1}^2 + 0.583 \sigma_{t-1}^2 + 0.255 \sigma_{t-2}^2 + 0.859 | \hat{R}_t | + 0.642 | \hat{R}_t^b | \\
(0.00) (0.00) (0.00) (0.11) (0.00)
\]

ARCH- LM (4) 0.745 (0.94) Log likelihood -651.72

where \( \hat{\varepsilon}_t \) is percentage change in Re/US$ exchange rate; \( \hat{R}_t^s \) measures percentage change in official sale of foreign exchange in the market; \( \hat{R}_t^b \) measures percentage change in official purchase of foreign exchange in the market; and \( \nu_t \) is a white noise process. The ARCH –LM test that follows \( \chi^2 \) distribution suggests that there is no remaining ARCH effect in the
standardized residuals; hence, the variance equation adequately captures the ARCH effect in the errors of mean equation.

In the mean equation the coefficients with respect to selling and buying operation of the RBI are statistically significant having negative sign, which is very hard to interpret. This is also consistent with the findings of most of the earlier empirical studies. Nonetheless, the magnitude of coefficient with respect to selling operation is thrice as large as that with respect to buying operation. This indicates the fact that the RBI does not treat undue appreciation and depreciation of rupee on the same foot; confirming the presence of asymmetry in the exchange rate intervention policy.

As far as the focus of the present chapter is concerned, the estimates of variance equation are very crucial. The sum of the ARCH and GARCH terms sum to less one indicating that the variance is a stationary process. The coefficients with respect to the absolute selling and buying operation of the RBI are statistically significant and have positive sign; suggesting that intervention in the foreign exchange market triggers volatility. This is consistent with the argument that secret intervention or in other words intervention without official announcement which has been the practice of the RBI tends to create ambiguity in the market, which in turn triggers volatility in the exchange rate rather than moderating it.

As it is evident from Table 4.1, the absolute exchange rates return exhibit high serial correlation than the square of the return. Therefore, we present the estimates of A-PARCH model for exchange rate:
\[ \hat{e}_t = 0.062 + 0.100\hat{R}_t + \varepsilon_t \]
\[ \sigma_{t,140}^2 = -4.743 + 0.181(1|\varepsilon_{t-1}| + 0.114\varepsilon_{t-1})^{140} + 0.588\sigma_{t-1,140}^2 + 0.255\sigma_{t-2,140}^2 + 0.547|\hat{R}_t| \]
\[ \text{ARCH-LM (4) 1.201(0.87) Log likelihood - 650.55} \]

\[ \hat{e}_t = 0.015 - 0.234\hat{R}_t - 0.055\hat{R}_t^s + \varepsilon_t \]
\[ \sigma_{t,101}^2 = -4.217 + 0.181(1|\varepsilon_{t-1}| + 0.095\varepsilon_{t-1})^{101} + 0.546\sigma_{t-1,101}^2 + 0.295\sigma_{t-2,101}^2 + 0.628|\hat{R}_t| + 0.435|\hat{R}_t^s| \]
\[ \text{ARCH-LM (4) 0.632 (0.96) Log likelihood - 646.73} \]

The evidence obtained from A-PARCH model is not qualitatively different from the GARCH model. The estimated power of the model is close to one; hence, Taylor/Schwert type model seems to fit the data better. Nonetheless, the log likelihood values indicate that the A-PARCH specification is better one than the GARCH specification. The best way to understand the significant different between these two models is to test the null hypothesis that the true model is GARCH against the alternative that the true model is A-PARCH. This hypothesis can be tested using the following statistics:

\[ 2(l - l_0) \approx \chi^2 \]

where \( l \) is the log likelihood from GARCH model and \( l_0 \) is log likelihood from A-PARCH model with two degrees of freedom. Therefore, the \( \chi^2 \) is \( 2(651.72-646.73) = 9.98 \) which is, for two degrees of freedom, significant at 1% level. This indicates that the A-PARCH model fits the data much better than the GARCH model. Overall, the empirical evidence shows that every official purchase seems to have less impact as compared to every sale of foreign.
exchange on exchange rate. Although intervention seems to trigger volatility, selling impact on exchange rate volatility is relatively larger. More importantly, the asymmetry coefficient in the A-PARCH mode (0.181) turned out to be positive and statistically significant; suggesting that volatility response is relative larger to appreciating rupee than to depreciating rupee.

Fig. 4.2: Conditional variance of percentage change in exchange rate (GARCH)

Fig. 4.3: Conditional variance of percentage change in exchange rate (A-PARCH)
The plots of conditional variance obtained from GARHC model and A-PARCH model are respectively presented in Fig. 4.2 and 4.3. The variance measures from both models appear to have symmetric trend and also aptly reflect higher volatility in exchange rate during Asian crises and the recent financial turmoil of the US.

4.4 Conclusion

Since the Reserve Bank of India has been focusing only on minimizing undue fluctuations in exchange rate through exchange rate intervention, this chapter is devoted to examine whether such official intervention during the sample has been successful in containing volatility of exchange rate. To this end, we estimated exchange rate equation using ARCH type models wherein the absolute amount of intervention is incorporated as an explanatory variable in the variance equation. In addition, instead of using the usual GARCH models in which the power of variables in the variance equation is determined a priori, we adopted the approach of Ding et al. (1993) which is popularly known as asymmetric power autoregressive conditional heteroscedastic model and allows the data to determine the power of explanatory variables in the variance equation.

The empirical estimation of the model was carried out using percentage change in exchange rate as dependent variable and size of intervention as explanatory variable in mean equation. In addition to GARCH terms, the variance equation includes absolute size of intervention as an explanatory variable to capture the impact of intervention on variance of exchange rate return. The results of simple GARCH model and APARCH model indicated that the RBI intervention triggers volatility and selling bring relatively larger volatility in exchange market. The evidence derived from the APGARCH model further indicated that the impact of intervention seemed to have been asymmetric in the sense that official selling of foreign exchange has larger impact on volatility as compared to what buying operations had.