Relationship between exchange rate volatility and central bank intervention: An empirical analysis for India

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ABSTRACT

In the world of high capital mobility, several risks are emerging in the financial markets and the central bank intervention has played an important role in managing the risks. In India, the Reserve Bank of India intervenes in the foreign exchange market to maintain an orderly market conditions. This paper empirically explores the relationship between central bank intervention and exchange rate behavior in the Indian foreign exchange market. Specifically, the paper investigates the effects of RBI intervention on exchange rate level and volatility. The study uses monthly data on Rupee-US Dollar bilateral exchange rate, net FII inflows, net dollar purchases of RBI, treasury bill rates of India and the US over the post-reform period, June 1995 through December 2005. Using GARCH (1,1) model, it is found that the intervention of RBI is effective in reducing volatility in the Indian foreign exchange market. However, the result is not supporting the theoretical positive association between exchange rate return and RBI intervention. Thus, the Reserve Bank intervention has been reducing the extent of fluctuations of the exchange rate rather than changing the direction of the rupee movement against the US$.

1. INTRODUCTION

The early 1990s marked a major shift in the economic policies of the government of India, with the introduction of a liberal policy regime that allowed greater freedom for foreign financial inflows into the economy. The opening-up of the Indian economy eased restrictions on capital flows – from earlier regime of official and commercial borrowing to private capital flows in the form of FDI and portfolio investment. In 1992, India initiated the process of integration of its financial markets with global financial markets by

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permitting foreign institutional investors (FIIs) to invest in Indian capital market and allowing domestic companies to raise capital from abroad through GDRs and ADRs. Further, movement towards full capital account convertibility has gained momentum in recent years. As a result, there is a surge in foreign exchange inflows, which has not only led the rupee to appreciate but has also added uncertainties to the financial markets and increased speculation in the foreign exchange market. With a view to curb excessive or undue fluctuations in the rupee value visa-vis other currencies and to correct misalignment, the RBI intervenes in the foreign exchange market with purchase or sale of foreign exchange.

There have been several international studies carried out on the effectiveness of Central Bank intervention in the foreign exchange market, but very few in the Indian context. The results, both at the international level and in India, lack unanimity about the efficacy of central bank intervention. Different models give different results, which may be due to lack of sound theory, differences in the choice of the model and/or the data period. Hence, there is scope for further research and exploration. Earlier studies for India have used relatively short time series data and simple econometric methods. We propose to use longer time series data and advanced econometric methodology. We believe, therefore, that our study may shed some new light on the effectiveness of RBI intervention in the foreign exchange market in India.

This paper intends to examine the empirical relationship between the central bank intervention and the exchange rate behaviour in India. For this purpose, the monthly data for the period June 1995 to December 2005 on India-US bilateral nominal exchange rate, net FII inflows, net interventions of the RBI, interest rate differential and inflation rate differential between India and the US are used. Among the various model alternatives, GARCH (1, 1) model has been found to be suitable and estimated. The paper is organized as follows: The following section reviews the theory and some empirical studies on central bank intervention. Section III deals with the specific objectives and database used in this study. Section IV discusses the empirical findings and finally Section V contains the conclusions.

2. SELECT LITERATURE REVIEW

Intervention, more specifically direct intervention, can be defined as the purchase and sale of foreign exchange assets by monetary authorities. The purchase (sale) of monetary authority that leads to an increase (decrease) in the monetary base is non-sterilized intervention. When the authority simultaneously or with a very short time lag take the necessary steps to offset the effects of the change in official foreign asset holdings on the domestic monetary base, it is called sterilized intervention. Non-sterilized intervention affects exchange rate by inducing changes in the stock of the monetary base. The effect of sterilized intervention on exchange rate is a matter of debate as it leaves the monetary base unchanged.

Sterilized intervention, generally, is thought of to work through three channels, namely Portfolio Balance channel, Signaling channel and Noise-trading channel. In the portfolio balance channel, domestic and foreign assets are assumed imperfect substitutes. Investors allocate their portfolios to balance exchange rate risk against expected rate of return so intervention could lead to a change in the value of the exchange rate. When the central bank sells foreign currency assets for domestic currency assets, other things being equal, this creates an excess supply of foreign currency assets, and an excess demand for domestic currency assets. To re-establish the equilibrium economic agents need to be compensated by a higher expected return on foreign currency assets. This may take the form of a widening interest-rate differential, or an appreciation of the domestic currency. Thus, even sterilized intervention could have an effect on exchange rates. There is however, not much empirical support for the working of intervention through this channel. Dominguez and Frankel (1993) were the first to find some evidence in favor of this channel. Obstfeld (1983), Rogoff (1984), Lewis (1988) have studied the relationship between central bank intervention and exchange rate behaviour through portfolio balance channel. However, their results remained inconclusive as they found either a wrong sign or insignificant coefficient for the relative asset supplies. A similar kind of conclusion was arrived at by Bhaumik and Mukhopadhyay (2000) in the Indian context.

The portfolio balance model cannot work if the assets are perfect substitutes. However, sterilized intervention could still be effective in influencing the exchange rate through the signalling channel (Mussa, 1981). This model assumes asymmetric information between market participants and the central bank. Sterilized intervention then operates through the signalling channel by causing private agents to alter their exchange rate expectations. For instance, the central bank might signal a more contractionary monetary policy by buying domestic currency in the foreign exchange market. The market participants will expect a tighter future monetary policy and will revise their expectations of the future exchange rate. If market participants judge the foreign exchange operations of the central bank to be credible, they will— although today's money supply remains unchanged— reshape their expectations on future monetary policy and hence reassess their expectations on future spot rates.

Empirical studies on signalling have yielded varying results. Dominguez (1990) studies the relationship between weekly data on money surprises and intervention, and concludes that intervention anticipates monetary policy. Klein and Rosegren (1991) find the impact of intervention declines with time, while Kaminsky and Lewis (1992), on using a regime-switching model, find inconclusive evidence as to whether intervention correctly signalled changes in monetary policy. Fatum and Hutchison (1999) investigated whether daily intervention operations in the United States are related to changes in expectation over the stance of future monetary policy using a GARCH model for the period 1989-93. They concluded that the interventions of Federal Reserve appear to have significantly increased the conditional variance of Federal funds futures rate as the conditional variance is positively and significantly related to the magnitude of intervention operations.

The Noise-trading channel can operate even when intervention is carried out discreetly and hence does not provide a signal to market participants, or when it is not large enough to alter the relative supply of assets denominated in domestic and foreign currencies in a significant way. A central bank can use sterilized interventions to induce noise traders to buy or sell currency. The idea underlying this channel is that a central bank can manipulate the exchange rate by entering in a relatively thin market and, on a minute-by-minute basis; the exchange rate is determined by marginal demand and supply flow in the foreign exchange market. However, there is only less number of studies exist on noise-trading channel. Goodhart and Hesse (1993), and Hung (1997) found supportive evidence for noise-trading hypothesis that the authorities prefer to intervene in relatively thin markets.

In the more recent literature, the effectiveness of central bank intervention is examined through its impact on exchange rate volatility, where the volatility variable used is either conditional volatility or implied volatility, calculated through GARCH models and from currency option pricing models respectively. In several cases, it is found that intervention increases the volatility in the foreign exchange market. Almekinders and Eijffinger (1994) using conditional volatility estimated by the GARCH model, find that intervention by the Bundesbank and US Federal Reserve were not successful in systematically reversing unwanted movements in the mark-dollar and yen-dollar exchange rates.

Dominguez (1998) explores the effects of foreign exchange intervention on the behaviour of dollar-mark and dollar-yen exchange rates. She finds that secret interventions generally increase volatility. Her study indicates that intervention had effects on volatility that are situation specific and can be positive or negative. Aguilar and Nydahl (2000) investigate the impact of intervention on the level and volatility of the Swedish Krona (krona-dollar and krona-mark rates) from January 1993 to November 1996. They use a bivariate GARCH model and the implied volatility approach from currency options. They find no significant effect for the exchange rate level and only weak evidence for a reduction in volatility for the whole period.

Daroodian and Caporale (2001) use a daily measure of exchange-rate intervention in the yen-dollar exchange markets for the period January 1985 to March 1997. While they find a statistically significant impact of intervention on spot rates, using ARCH(8)-M and ARCH(8) models, they show that the official sales of dollars against either currency are associated with dollar depreciation and the intervention operation led to an increase in uncertainty in the foreign exchange market.

In Indian context, Pattanaik and Sahoo (2003) using the models of Almekinders (1995), Bonser and Neal (1996), and Almekinders and Eijffinger (1994), find that intervention may not be effective in influencing volatility in the expected direction. Likewise, Unnikrishnan and Ravi Mohan (2003), using ARCH procedure for the period January 1996 to March 2002, find that the RBI intervention affected the exchange rate level and volatility in the expected direction, though the coefficient in the mean equation was insignificant.

As the above brief survey shows, opinions seem to differ on whether central bank intervention really can stabilize exchange rate or not. Some analysts believe that central bank intervention can reduce exchange rate volatility by stopping speculative attack against a currency. Others argue that intervention may increase volatility if it contributes to market uncertainty or encourages speculative attacks against the currency. Theoretically, intervention may work through different channels. However, RBI partially sterilizes its intervention in the foreign exchange market, hence it is not clear whether it would be effective or not. This issue needs re-examination. The present study attempts to do that using recent data and the GARCH method.

3. DATA AND METHODOLOGY

3.1 Data:

The data period chosen for the empirical analysis is June 1995 to December 2005, and the data frequency is dictated by the availability of data on RBI intervention. All the data are monthly series and have been collected from “RBI Monthly Bulletin”, “Handbook of Statistics on the Indian Economy (2003-04)”, “International Financial Statistics”, “Federal Reserve Bank of St. Louis” and “Securities and Exchange Board of India” database. The variables used in this study are: (i) RBI intervention in Indian foreign exchange market, (ii) exchange rate return, (iii) interest rate differential and (iv) net FII inflows (FII). The (net) intervention variable (Inv) is defined as the net purchases of the US dollars by the RBI, i.e. the difference between purchases and sales of foreign exchange by the RBI in core of rupees at contract rate. RBI purchases and sales of foreign exchange include spot, swap and forward transactions in the foreign exchange market. The exchange rate return is computed as, $Return_t = 100 \times (\ln S_t - \ln S_{t-1})$, using the bilateral India-US nominal spot exchange rate, Re/$, (S).

Since movements in exchange rate are likely to be influenced by not only RBI intervention, but also other macroeconomic variables, we have included interest rate differential between India and the US in our model. The interest rate differential (IntD) is the difference between Indian 91-days Treasury bill rate and US 3-month Treasury bill rate, with monthly data on both series. Since foreign institutional investors are playing a dominant role in stock market and FII inflows are more volatile in recent period (Figure-2), they may have an impact on exchange rate return. S, we have used net FII inflows as a determinant of exchange rate return and volatility. The net FII inflow is the net purchases of debt and equity by the foreign institutional investors during a month expressed in rupees crores.

We have introduced one dummy variable by carefully examining the change in the extent of variation (volatility) in exchange rate return series (Figure-1). This coincides with the introduction of a package of policies (e.g. Resurgent Indian Bond, RIB scheme) that were announced by RBI in August 1998 in order to contain the effect of East Asian financial market crisis on Indian foreign exchange market. Therefore, a dummy variable (Dum) has been introduced to separate the sample period into two sub-periods, from June 1995 to July 1998 as pre-policy period and from August 1998 onwards as post-policy period. The dummy variable is assigned zero and one for the pre- and post-policy periods respectively. Interaction of this dummy variable with Inv (IDInv) is also considered. There are 127 monthly observations in the data.

3.2 Methodology:

The central bank intervention in the foreign exchange market affects exchange rate and its volatility by changing the market fundamentals, expectations of future fundamentals or policies, and speculative bandwagons. This is usually quantified through a regression model. In this study, we have related RBI intervention to exchange rate level and its volatility using GARCH (1,1) model.

The proposed model is as follows:

$$Return_t = a_0 + a_1 Inv_t + a_2 FII_t + a_3 IntD_t + a_4 InflD_t + a_5 IDInv_t + a_6 Dum_t + \varepsilon_t \quad (1)$$

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, h_t)$$

$$h_t = b_0 + b_1 Inv_t + b_2 FII_t + b_3 IntD_t + b_4 InflD_t + b_5 IDInv_t + b_6 Dum_t + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \quad (2)$$

with $b_0, \alpha, \beta > 0$ and $\alpha + \beta < 1$.

Equation (1) represents the mean equation in which the dependent variable is rate of return on nominal exchange rate (S_t) during a month. It is assumed that the average return depends on net purchases of RBI (Inv), net FII inflows (FII), interest rate and inflation rate differentials between India and the US (IntD, InflD), the dummy variable (Dum) and its interaction with intervention ($IDInv$), equal to $Dum \times Inv$. Further, it is also assumed that the random disturbance term in the mean equation (ε_t) has a conditional normal distribution[1] with mean zero and variance h_t. Here, Ω_{t-1} indicates all the (lagged) information available to the participants in the foreign exchange market at time t. According to theory, the intervention of a central bank is said to be effective if the coefficient a_1 is positive and significant. That means the increase in net purchases of RBI leads to increase in exchange rate return. Thus, Indian rupee depreciates against the US \$ as the net RBI purchases increase.

In equation (2), the conditional volatility depends on the same set of determinants as that of the mean equation (1) along with two more determinants in the form of ε_{t-1}^2 and h_{t-1}. RBI intervention is said to be effective if an increase in net purchases of dollars lowers the volatility of the monthly Re/\$ returns. Hence, the expected sign for b_1 is negative.

4. EMPIRICAL ANALYSIS

[1] Alternatively, the error term may be assumed to follow a Student's t-distribution.

4.1 Unit root tests:

It is customary to verify the stationarity of the variables that appear in any time series regression. In our case, the presence of unit roots for all the variables in the mean equation are tested by applying DF, ADF and PP tests and it is found that all the variables are stationary at 1% or 5% level of significance. The RBI intervention series however exhibits stochastic trend but stationary at 1% level (Figure-3).

Likewise, the use of standard ARCH/GARCH model requires testing the distribution of the exchange rate return series. To verify this requirement, we have computed the descriptive statistics of the exchange rate return, including skewness and kurtosis measures. These measures indicate that the exchange rate return series is positively skew and leptokurtic, which indicates the presence of volatility in the return series. Further, the J-B test has rejected the null hypothesis of normal distribution for this variable with high level of confidence. This confirms the non-normality of the return series.

4.2 Tests for ARCH effects:

Before estimating the ARCH/GARCH model, it is necessary to test the presence of time varying heteroscedasticity in the data. To test the ARCH effect, we have estimated equation (1) applying OLS technique and obtained the estimated residuals. The Ljung-Box Q-statistic for the residuals as well as squared residuals showed insignificant autocorrelation coefficients up to lag length of eight. However, the ARCH-LM test and the Ljung-Box Q-statistic for squared return series confirms the presence of ARCH effect as the null hypothesis of zero autocorrelation of squared residuals as well as squared return are rejected (Table-1). Thus, the estimated residuals and hence the monthly exchange rate return series is a heteroskedastic martingale process and it follows a non-normal distribution.

4.3 GARCH (1,1) model:

After the confirmation of ARCH effects, we estimated the GARCH model with different lag lengths using maximum likelihood method, which assumes normality of errors. The estimated coefficients (signs) and their statistical significance were not satisfactory. This prompted us to give up normality assumption and use Bollerslev-Woodbridge's quasi-maximum likelihood (QML) method. This method involves non-linear estimation and so we have used Berndt-Hall-Hall-Hausman (BHHH) numerical algorithm [Berndt et al. (1974)] using Student's t–distribution. The estimated results of the GARCH (1,1) model are presented in Table-2. It is customary to check the absence of ARCH effects after estimating the chosen model. Using the LB-Q test statistic we do not reject the absence of (further) ARCH effects in the residuals from the GARCH model. This is once again confirmed by ARCH-LM test up to 8 lag length.

To assess the degree of volatility persistence, we have used the Wald test. The null hypothesis of this test is $\alpha + \beta = 1$, i.e. 'the error variance is integrated or non-stationary' against the alternative $\alpha + \beta < 1$ or error variance stationary. In our case, the null hypothesis is rejected with high confidence level and the sum of ARCH and GARCH coefficients, $\alpha + \beta = 0.77$, which is substantially lower than unity. This confirms the stationarity of the variance and the presence of long memory. Further, the test statistic being less than unity, it is still mean reverting[2]. All these results confirm the adequacy of our GARCH model.

4.4 Parameter estimates:

Though we have two equations, one each for the mean and variance, which are estimated together as a system, we will discuss the results of each equation separately. In the mean equation (Table-2), we did not get the expected positive sign for the coefficient of intervention variable.[3] The coefficient (a_1) is negative and highly significant. It implies that for each 1 crore rupee worth net purchases of US dollar by the RBI, the exchange rate return will fall by 0.0002 during the pre-policy period (before August 1998). Thus, increase in the net purchases (sales) of RBI may not lead to depreciation (appreciation) of

[2] Volatility will not take long time to revert to mean as $\alpha + \beta = 0.77$, which is substantially less than unity.

[3] Some analysts feel that the unexpected sign may be due to the monthly nature of the intervention data used. In reality, RBI intervenes daily or even more than once on some days and sometimes it does not intervene at all. The central bank makes available intervention data only on monthly basis. It is also said that there may be 'lumpiness' in the RBI intervention activity- heavy purchases on a day at the behest of big dealers or companies and phase-out sales during the rest of the month. Such actions may not be amenable for accurate modeling and may even lead to confounding and unexpected signs of the coefficients.

the rupee in the Indian foreign exchange market during the pre-policy period. This, on the face of it, appears surprising. The nature of effect on exchange rate is not established in this case, and much depends upon the kind of signals that are being generated.[4]

In the post-policy reform period, taking into consideration the coefficient of interaction dummy variable, the coefficient of intervention variable will be –0.00005, which is still negative but substantially lower. The effect of intervention on return will be similar as before. Thus, there is a tendency towards correct response in the post-policy reform period. Further, there is positive relationship between exchange rate return and FII inflows of one period lag, though the relationship is not highly significant[5].

The estimated coefficients of the variance (volatility) equation reflect the correct response of intervention on volatility. The crucial parameter of interest in the variance equation is the coefficient of intervention variable (b_1). This coefficient is expected to be negative to say that the RBI intervention is "effective", i.e. due to RBI intervention (net purchases) in the foreign exchange market, the volatility in the exchange rate will decline[6]. The empirical result seems to support this with high degree of confidence. Several other studies also have found similar results (e.g. Pattanaik and Sahoo, 2003; Anguilar and Nydahl, 2000). Thus, the results suggest that the RBI intervention is effective in reducing volatility in foreign exchange market.

The coefficients of lagged squared residuals and lagged conditional variance have expected signs and the latter is highly significant whereas the lagged squared residual coefficient is significant at less than 10% level in the variance equation. Therefore, lagged volatility has more significant effect on the current volatility. The intercept term (during

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[4] In one version of the model, the RBI purchases and sales of US dollar are included as separate variables. Even here, the problem of wrong sign persisted and the results for variance equation were not appropriate. Since RBI is intervening in the market to correct disorderly market conditions, this type of result is not surprising.

[5] Since the current FII inflows have no significant effect on exchange rate return, the variable is included with one period lag in the mean equation.

[6] Monthly volatility in exchange rate (standard deviation) has also been computed using daily data on spot exchange rate for the period May 1998 to April 2004. A simple correlation coefficient between monthly volatility and RBI intervention was found to be –0.31.

pre-policy period), ARCH coefficient and GARCH coefficient are positive, as required by the GARCH model. The volatility seems to be affected significantly by both the interest rate differential and FII inflows signifying that the interest rate differential between India and the US has negative impact on volatility whereas more FII inflows are increasing exchange rate volatility. These latter two responses have important policy implications for controlling volatility in exchange rate return.

5. CONCLUSION

There is a general concern that high capital inflows not only lead to appreciation of the rupee, which erodes India's competitiveness in the international market but also increases volatility in the foreign exchange market. To maintain the value of the rupee and control volatility, the RBI intervenes in the foreign exchange market The RBI's policy intention is to contain volatility instead of removing it completely. The results from GARCH model confirms that the intervention of RBI is effective in reducing volatility in the Indian foreign exchange market. However, the result is somewhat contrary to the theory in the context of the relationship between exchange rate return and RBI intervention. Thus, the Reserve Bank intervention has been reducing the extent of fluctuations of the exchange rate rather than changing the direction of the rupee movement against the US dollar.

Figure 1: Trend in nominal bilateral exchange rate return (%)

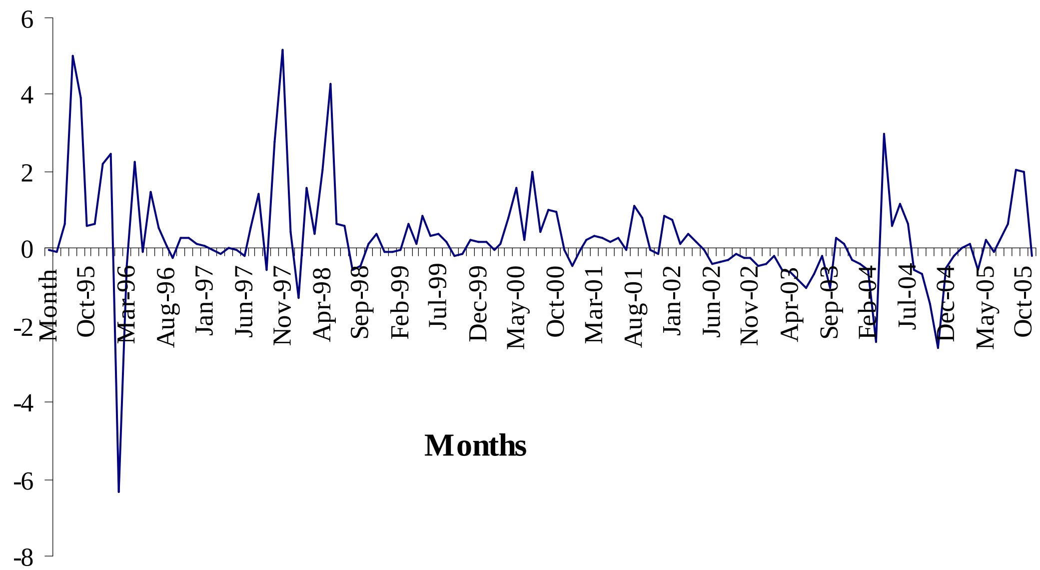

Figure 2: Trend in FII inflows (Rs. in Crore)

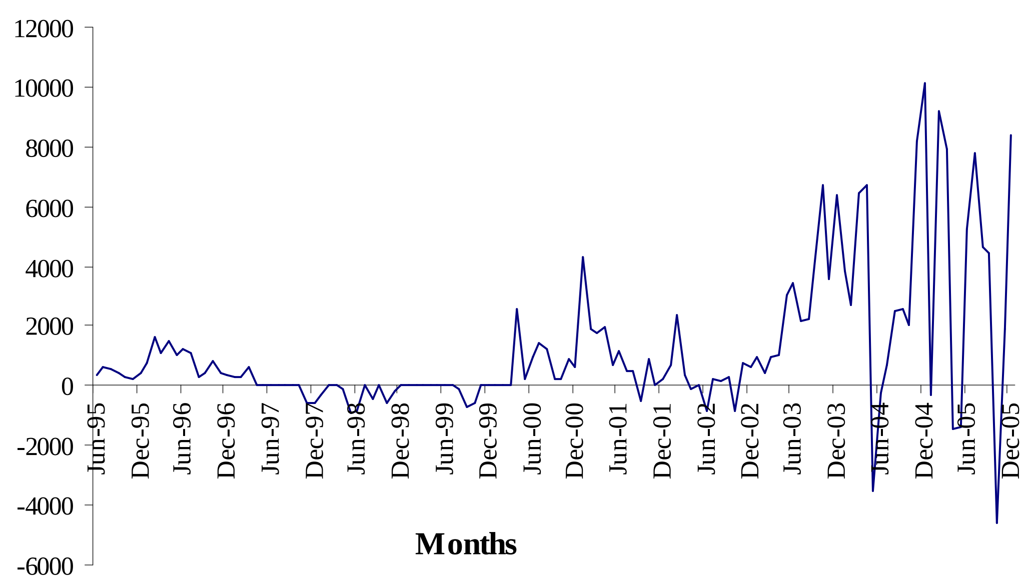

Figure 3: Trend in net purchases of foreign exchange by the RBI (Rs. in Crore)

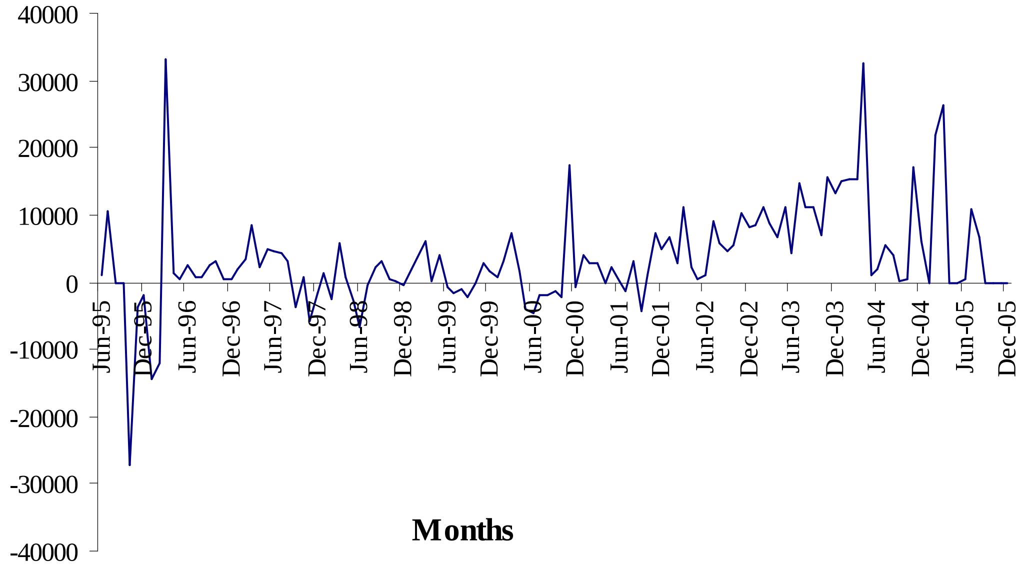

Table-1: Estimated test statistics of ARCH effect

Variable	**Q(8)**	**Q^2(8)**	**LM(8)**
ε_t	5.25 (0.73)	6.29 (0.62)	14.12 (0.08)
Return	12.41 (0.13)		
$(\text{Return})^2$	26.73 (0.00)		

Note: 1. Q and Q^2 are the LB Q-statistics for residuals and squared residuals respectively. The figures in parenthesis are the lag length chosen for the test.

2. Figures in parenthesis of the table entries are the probability value to test the ARCH effect.

Table-2: Parameter estimates of the GARCH (1,1) model

	Coefficient	t-Statistic	P-Value
Mean Equation			
C	0.77496	2.50528*	0.012
$\boldsymbol{Inv_t}$	-0.00019	-6.61699*	0.000
$\boldsymbol{FII_{t-1}}$	0.00004	1.54446	0.123
$\boldsymbol{IDInv_t}$	0.00014	4.57026*	0.000
$\boldsymbol{Dum_t}$	-0.61778	-1.93772*	0.053
Variance Equation			
C	0.67911	5.76041*	0.000
ε^2_{t-1}	0.20874	1.7518***	0.080
h_{t-1}	0.56336	7.51215*	0.000
$\boldsymbol{Inv_t}$	-0.00001	-2.24370**	0.025
$\boldsymbol{IntD_t}$	-0.04675	-2.83205*	0.005
$\boldsymbol{FII_t}$	0.00006	3.42832*	0.001
$\boldsymbol{Dum_t}$	-0.43836	-2.61171*	0.009

$\overline{R}^2$ = 0.40 F-stat = 7.9 (0.000)*
DW = 1.92 Wald Stat = 7.09 (0.007)*
Log likelihood = -143.28
AIC = 2.46 SC = 2.75 LM(8) = 1.43 (0.994)

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