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The Effectiveness of Central Bank Intervention in The Foreign Exchange Market: Evidence From India.

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Abstract:

This paper analyzes the effectiveness of RBI intervention and its asymmetric impact on the exchange level and volatility in the foreign exchange market. The peculiarity of this study is to verifying whether RBI intervention leads to asymmetric effect on exchange rate or not using purchases and sales of US dollar as separate variables in the empirical specification. To estimate intervention effects, we use the monthly data on the exchange rate and intervention for the period July 1995 – July 2013 applying GARCH model. In the first empirical model results, intervention through net purchases of US dollar doesn't not show any significant effect on the exchange rate level and however, it reduces the exchange rate volatility. These results are consistent with RBI stated objective that RBI aims to mitigate Rupee/USD exchange rate volatility leaving exchange rate level market forces in the foreign exchange market. The empirical results in second model suggest that RBI intervention neither with purchases or sales affects significantly exchange rate level. However, this implies that RBI follows a leaning against the wind policy during appreciation of the rupee whereas during depreciation of the rupee, a leaning with wind policy as signs effect of each coefficient indicates. Similarly, purchases are associated with a fall in volatility while sales are associated with a rise in volatility in the exchange rate volatility implying that RBI intervention is more effective in minimizing volatility during appreciation of

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the rupee rather than during depreciation of the rupee against US dollar in the foreign exchange market. Thus this result provides some evidence on the asymmetric effect of intervention. This study also recommends that RBI should practice polices that improves credibility on sale intervention in the foreign exchange market as their adding fuel to volatility nature.

Key words: Central bank intervention, net purchases, purchases and sales of US dollar, exchange rate level and volatility, GARCH, asymmetric effect.
JEL: E58, F31, F3

1. Introduction:

In the 1970's , A major industrial countries adopted the floating exchange rate system in which market forces to determine the exchange rate value of domestic currency price in terms of foreign currency. This led to a larger uncertainty or volatility due to speculative attacks in their foreign exchange rate market (Sarno and Taylor, 2001). Thus, a necessity of intervention by monetary authorities or central bank has been enhanced dramatically in the foreign exchange market. As per IMF Guidelines, *its member can react, if necessary, with intervention in order to avoid short run fluctuations and bring orderly market with taking into account the interest of other member in whose currencies they intervene in the foreign exchange market.* India also as an emerging economy has been intervening in the foreign exchange market, whenever necessary though it has adopted floating exchange rate polies since 1993 March. This is reason why IMF considers India as a country that follows a managed floating exchange rate system without any pre-determined target exchange rate. According to Jalan (1999), under this system, market forces such as demand and supply condition determine rupee dollar exchange at larger extent and also *Reserve Bank of India (RBI) as a central bank of India pursues foreign exchange market intervention to mitigate the exchange rate uncertainty or volatility, promote export competitiveness, accumulate foreign reserves and develop an orderly market conditions.* Thus, RBI intervenes in the foreign exchange market. Figure.1 demonstrates trends in RBI intervention proxied by the net purchases of US Dollar for the period 1995 to 2013 in which that RBI has been intervening with its buying the dollar more than selling the dollar in the foreign exchange

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market. This indicates that RBI has been intervening to stop the appreciation rupee rather than depreciation of rupee against dollar (Ramachandran and Srinivasan 2007). However, negative net purchases of dollar after 2008 indicates that RBI has intervened to curtain depreciation of rupee against the dollar in the foreign exchange market. Figure.2 also shows trends in foreign exchange reserves in India which is another proxy for intervention during the period 2000-2011, reserves with the RBI have increased substantially from 45 billion US dollars to 293 billion US dollars in 2013 and this can be attributed to large purchase of US dollars by the RBI by intervening in the foreign exchange market. Thus, this provides evidence for RBI has been intervening in the foreign exchange market from time to time whenever necessary.

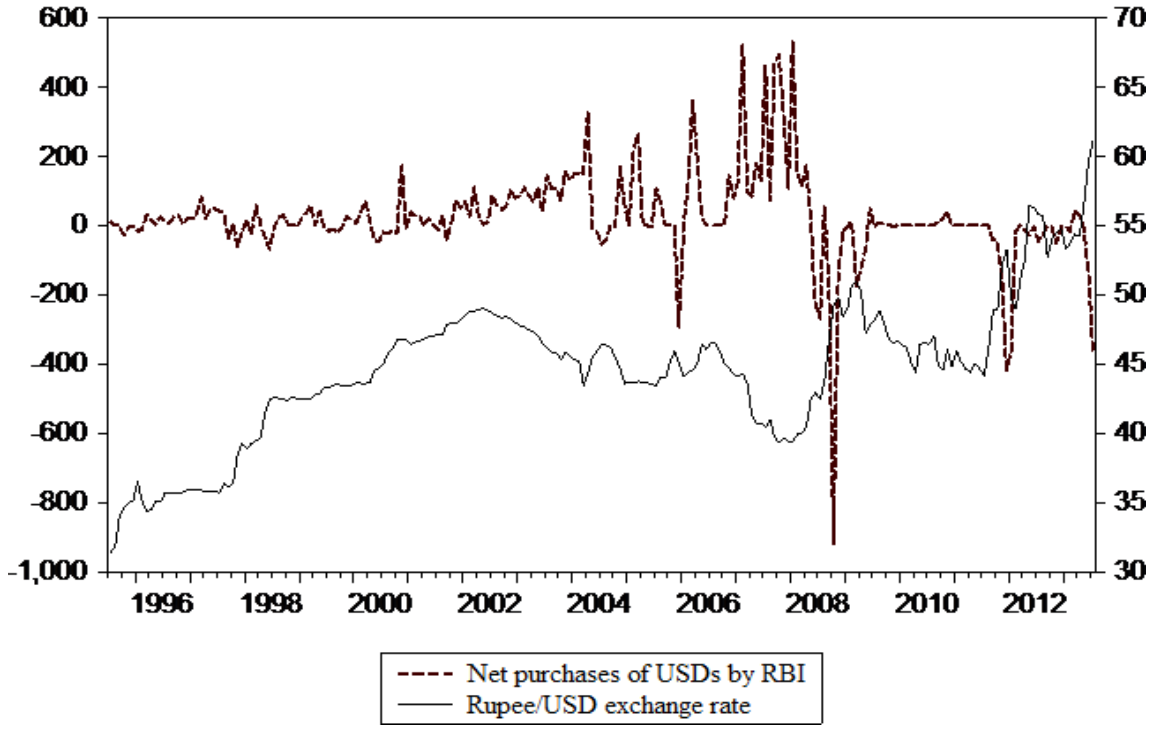

Figure.1 Trends in Net Purchases of US dollar by RBI and exchange rate

There are plenty of studies in the Indian context that examine the effectiveness of central bank intervention by taking net purchases of US dollar by RBI as a proxy for intervention such as Pattnaik and Sahoo (2003), Behara et al.(2006), Unnikrishan and Mohan (2003) and Goyal and

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Arora (2012) etc. Since there is dearth of studies examining the asymmetric impact of intervention on exchange rate. This present study focuses on asymmetric impact of RBI intervention on the exchange rate by taking purchases and sales of US dollar by RBI as separate variables in the empirical model and investigates its asymmetric effect on the exchange rate level and volatility. Thus, this paper has two objectives. One is to examine the effectiveness of RBI intervention on Rupee/USD exchange rate level and volatility. Second is to verify relevance of its asymmetric effect on the Rupee/USD exchange rate for the period spanning from July 1995 to July 2013. This study applies GARCH (1,1) to estimate the condition exchange rate level and volatility with intervention specific models. The empirical results suggest that though intervention with net purchases of US dollar is not effective in the influencing the Rupee/USD exchange rate level, it reduces the exchange rate volatility in the foreign exchange market. Similarly, intervention with neither purchases nor sales of RBI affects the exchange level. However, these results suggest that the RBI follows a leaning against wind policy during appreciation of the rupee whereas during depreciation of the rupee, a leaning with wind policy. This gives some support for asymmetric intervention by RBI. Surprisingly, purchase reduces volatility and sale increases volatility of exchange rate. Therefore, this provides evidence for asymmetric impact of RBI intervention and suggests that RBI is more effectives at curbing volatility during appreciation of the rupee rather than depreciation of the rupee against US dollar in the foreign exchange market.

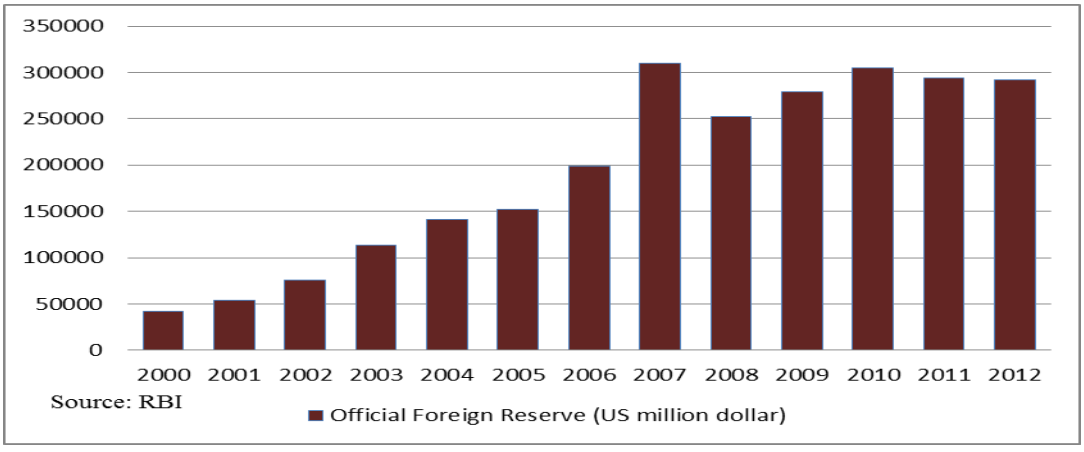

Figure.2 India Intervention Trends

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This paper is organized as follows: section 2 provides a theoretical foundation on the central bank intervention and reviews the empirical literature on the effectiveness of intervention. Section 3 presents the empirical models of intervention specific. Section 4 details data and data sources. Section 5 describes about Econometric methodology and results are summarized in Section 6 followed by Section 7 highlights conclusion and policy implications.

2. Review of Literature

It is better to have idea on the theoretical background on the central bank intervention to explore the widely intervention effects on the exchange rate through which it operates. In principle, central bank intervention shows its impact through four channels by bringing changes in the monetary base of an economy consists of two components i.e., Net Foreign Assets (NFA) and Domestic Credit (DC): Symbolically, it can be described as:

$$M=NFA+DC \quad (1)$$

Where any change in NFA or DC will have a proportionate change in monetary base as when central bank intervenes with buying and selling Foreign assets (foreign currency) in the foreign e exchange market, NFA will change and thereby change in the monetary base. Based on the monetary base, the central bank intervention can be classified as sterilized and non-sterilized. Sterilized intervention in which intervention impact on the monetary base is zero since central bank takes counter action to the effect of a change in NFA on domestic monetary base by conducting open market operation i.e., equation (1) will be as $\Delta M=\Delta NFA+\Delta DC=0$ whereas sterilized intervention in which intervention have impact on the monetary because central bank buy and sell foreign asset without the intentions of offsetting the changes in NFA thereby, resulting into effect on monetary base. i.e., equation (1) will be $\Delta M=\Delta NFA+\Delta DC=0$.

As said, intervention has the four channels through which it operates. In Monetary channel, intervention affects exchange rate through the resultant change in interest rate as buying or selling foreign currency by central bank in the foreign exchange market changes domestic money base (Brissimis and Chionis, 2004). This channel is related to non-sterilized intervention. Second channel is portfolio channel related to sterilized intervention. In this channel, when domestic and foreign assets are imperfect substitutes, central bank intervention with purchases and sales of

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foreign currency changes the relative supplies of domestic and foreign assets or bonds. This may affect exchange rate in the foreign exchange market as market agents rebalance their portfolios and equalize risk-adjusted returns (Guimaraes and Karacadag, 2004). Third channel which works despite of perfect substitutes between domestic and foreign assets is called signaling channel. Under this channel, intervention affects the exchange rate by influencing the expectations about future monetary policy (Mussa, 1981). Finally, intervention also affects exchange rate through order flow channels in which huge order flows (either positive or negative) created by intervention of buying and selling foreign currency in the foreign exchange market (Disyatat and Galati,2007). This is also known as Microstructure channel.

We review the empirical literature on the effectiveness of central bank intervention and its asymmetric impact on the exchange rate. In fact, there are three views on the effectiveness of intervention. First view, intervention can be effective if it influences exchange rate level and reduces volatility. Second view, intervention can be effective, if it alters exchange rate direction, i.e., reversing the ongoing movement, however the intervention may be counterproductive because it increases volatility in the foreign exchange market. Third view, intervention shows a marginal impact on the exchange rate level and volatility (Edison et al. 2003).

Bonser-Neal and Tonner (1996) analyze the impact of coordinated intervention by Federal Reserve of US, Bundesbank of Germany and Bank of Japan (BOJ) for the period 1985-1991 using implied volatility method[3] to measure the exchange rate volatility. They find that intervention is associated with a positive or no change in the exchange rate volatility. Dominguez (1998) focuses the impact of central bank intervention on the exchange rate for the period 1987-1994. She suggests a mixed effect of intervention that intervention can either reduces or increase the exchange volatility in time varying period and further, reported intervention reduces exchange rate volatility while secret intervention increases exchange rate volatility. Brissmis and Chionies (2004) finds that using GARCH model for short period spanning from 1999-2001 in the context of Euro Central bank and BOJ, secret intervention is more potent than reported intervention in the influencing exchange rate. Bein et al (2003) suggest that using Markov

[3] This is an alternative approach to measure the exchange rate volatility using option prices. Specifically, Black-scholes model (1973) is used to measure the volatility which relates the prices of call options (Angular 2000).and Nydahl

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Switching model, intervention leads to a stabilizing effect when the market is more volatile and intervention is unambiguously expected whereas intervention leads to destabilization effect on the exchange market when market is less volatile and expected intervention is more ambiguous. Aguilar and Nydahl (2000) examine the effect of intervention of Swedish Central Bank on the exchange rate level and volatility for the period 1993-1996. This provides a weak evidence for influence of intervention on the level of exchange rate and support for reduction in the exchange rate volatility.

Galati and Disyatat (2005) analyze the impact of intervention of Czech National Bank (CNB) on the exchange rate spot and implied exchange rate volatility for the period September 2001-October 2002. Using instrumental method, the empirical results conclude that Czech National Bank (CNB) intervention has weak impact on the spot exchange rate and risk reversal and intervention does not show any impact on exchange rate volatility. Further, Czech National Bank seemingly responses to the appreciation of Koruna. Gilati et al. (2005) suggest that Bank of Japan intervention is ineffective in influencing the exchange rate level and but intervention destabilizes exchange rate volatility in the foreign exchange market.

Futum and Hutchison (2003) examine the effectiveness of sterilized intervention with focusing on daily intervention of US and BudesBank on exchange rate for the period 1985-1995 applying event analysis method. They find that central banks intervention is effective and play a major role in determining exchange rate movements. Futum (2008) suggests, in the context of Bank of Canada that interventions are effective, some extent, in changing the movements of exchange rate and bringing smoothness in the movements of exchange rate and however, intervention is not associated with a reduction in the exchange rate volatility in his results analysis.

In case of Reserve Bank of Australia (RBA) for the period 1984- 2001 using event analysis and GARCH model, Edison et al (2003) observes in his empirically analysis that intervention has shown some effectiveness in moderating exchange rate movements during Australian dollar depreciation and but increases the exchange rate volatility. Simwake and Mkandawire (2012) examine Reserve Bank of Malawi (RBM) intervention on exchange rate level and volatility for the period 1995-2008. In GARCH results, it has found that RBM intervention affects the exchange rate level and leads to a rise exchange rate volatility.

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Another set of studies in this area of literature has tested whether intervention has asymmetric impact on the exchange rate. Asymmetric impact means how sale and purchase of intervention have different effect on the exchange rate. Frenkel et al. (2004) investigate the asymmetric impact of BOJ intervention on the exchange rate volatility derived by implied volatility method during the period 1999-2000. In the results, they find that the purchases of foreign currency are associated with a rise of exchange rate volatility whereas sales of foreign currency are associated with no impact on the exchange rate volatility in the foreign exchange market.

Guimaraiesa and Karacadag (2004) focus on the asymmetric impact on exchange rate level and volatility during the period august 1996-June 2003. Using the Asymmetric Component Threshold GARCH model, in the case of Mexico, the sale shows a small effect on the exchange rate level and similarly, sales increase exchange rate volatility compared to purchase. In case of Turkey, neither sales nor purchases affect the exchange rate level and similarly, both sales and purchases lead a fall of exchange rate volatility. Domec and Mendoza (2004) using EGARCH Model, suggests that sales show the more effect than purchases on the exchange rate level in the case of both countries. However, sales are associated with a reduction in the exchange rate volatility compared to purchases in the foreign exchange markets.

Mckenzie (2002) examines the asymmetric impact of RBA intervention on the exchange rate volatility applying GARCH and TGARCH for the period 12 December 1983-31 December 1997. The GARCH results show that sales leads to an increase of exchange rate volatility during the depreciation of the Australia dollar compared to purchases during the appreciation and TGARCH also confirms these results. Lahuara and Vega (2013), suggests the similar results in the context of Peru applying Event and Structural Vector Autoregressive Regression Model using the intraday data for span from January 5, 2009 – April 27, 2007. Broto (2012) finds that asymmetric impact in case of Chile, Colombia, Mexico and Peru where sales and purchases are different in terms of effect on the exchange rate volatility during period July 1996-January 2011 using GARCH Model.

There are few studies which analyze the effectiveness of central bank intervention in the Indian context. These studies give important insights about intervention effectiveness and its significance in the Indian foreign exchange market. Pattnaik and Sahoo (2003) examine that

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impact of RBI intervention on the exchange rate for the period using Two stage Least Square (TSLS) regression method. The empirical findings suggest that RBI intervention leads to appreciation of rupee instead depreciation against US dollar. However, intervention reduces the exchange rate volatility effectively. Using GARCH Model, Behara et al.(2006) also find the similar results for the period June 1995-December 2005. Unnikrishan and Mohan (2003) analyze the effectiveness of RBI intervention on exchange rate level and volatility for the period January 1996 to March 2002. The empirical results suggest that RBI intervention is not effective in influencing exchange rate level. However, intervention reduces exchange rate volatility. In the recent study by Goyal and Arora (2012) analyze the effectiveness of RBI intervention on exchange rate level using EGARCH. They find that intervention leads to appreciation of rupee against the US dollar and increase of exchange rate volatility.

Inoue (2012) investigates a causal relationship between intervention and exchange rate volatility for the period 1997 to December 2011. Using univariate EGARCH, he finds that there is causality from exchange rate volatility to intervention but not vice-versa in either spot or forward market. Thus, this study confirms that RBI uses foreign exchange intervention as measure to curb exchange rate volatility in the foreign exchange market.

We can find that there are lack of studies which analyze the asymmetric impact of RBI intervention on the exchange rate level and volatility in the India context. Therefore, this paper also focuses primarily on the asymmetric impact of RBI intervention on the exchange rate level and volatility by decomposing the net purchases of US dollar by RBI into purchases and sale with analyzing along with the effectiveness of RBI intervention in the foreign exchange market as well. Following section discuss about the empirical models which captures the effectiveness of RBI intervention and its asymmetric effect on the exchange rate level and volatility.

3. Empirical Model

We use two models to analyze the effect of RBI intervention on the Rupee/dollar exchange rate. The baseline model I is to examine the effectiveness of RBI intervention on the exchange rate level and volatility and model II is to verify the asymmetric impact of intervention on the exchange rate. Further each model contains an exchange rate level and volatility equations are given as below.

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Model I

$$r_t = \beta_0 + \beta_1 np_t + \beta_2 ir_t + \beta_3 ird_t + \beta_4 fii_t + \beta_5 dum_t + \varepsilon_t \quad (2)$$

$$h_t = \alpha_0 + \alpha_1 np_t \quad (3)$$

Model II

$$r_t = \gamma_0 + \gamma_1 p_t + \gamma_2 s_t + \gamma_3 ir_t + \gamma_4 ird_t + \gamma_5 fii_t + \gamma_6 dum_t + \varepsilon_t \quad (4)$$

$$h_t = \delta_0 + \delta_1 p_t + \delta_2 s_t \quad (5)$$

In equation (2) and (4), r_t is exchange rate returns measured in natural logarithm and np_t, p_t and s_t are the net purchases of US dollar, purchases and sales of US dollar proxied for intervention, and other variable such as ir_t, ird_t, fii_t and dum_t are interest rate, inflation rate, foreign institutional investment and monthly dummies are included to account their impact on exchange rate return. In equation (3) and (5), h_t is exchange rate volatility measured in the natural logarithm form. Here β's, γ's, α's δ's in the equations from (1) to (4) are parameter coefficients to be estimated through GARCH (1,1) methodology. ε_t stands for error term and t stands time.

Exchange rate returns (r_t):

We use monthly exchange rate return of Rupee/US exchange rate as a dependent variable in the exchange rate level equations. Exchange rate returns is defined as a natural logarithm difference between Rupee/US exchange rate at month t and t-1.

Exchange rate volatility (h_t):

This is a dependent variable in the exchange rate volatility equations and is derived by the GARCH (1,1).

Intervention (np_t):

We take monthly the net purchases of US dollar in billion rupees as an intervention proxy. This is an independent variable in the baseline model I. Intervention is said to be effective if net purchases of US dollar by RBI are positively related with exchange rate returns. This indicates that net purchases of US dollar by RBI leads to depreciation of rupee against the dollar in the foreign exchange market with raising the exchange rate return between two consecutive months.

Purchase (p_t) and Sale (s_t):

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Intervention may leads to asymmetric effect on exchange rate return and volatility in the Indian foreign exchange market. Thus, in order to observe the asymmetric effects on exchange rate, we decompose intervention into purchases and sales of dollar by RBI. Therefore, purchases and sales of US dollar are incorporated in the model II as independent variables. Generally, when domestic currency appreciates, the central bank purchases US dollars to moderate the appreciation, whereas when domestic currency depreciates, the central bank sells US dollars to moderate the exchange rate depreciation. Therefore, purchases (p_t) are positively and sales (s_t) are negatively related to exchange rate returns in the level equation. In the case of volatility, both purchases and sales are expected to moderate exchange rate volatility in foreign exchange market and hence a negative relationship is expected between p_t, s_t, and h_t. However, asymmetric impact of intervention is expected if purchases (p_t) and sales (s_t) are related with exchange rate volatility differently from one other.

Other variables, according to theory, such as interest rate (In_t) and net FII inflows (fii_t)are expected to be negatively related with exchange rate return, inflation rate differential (ird_t)is expected to have a positive relation with exchange rate returns and monthly *(dums)* impact is ambiguous on exchange rate return. The data and data sources, measurement of variables, methodology and empirical results are given in the following sections.

4. Data and Methodology

We use monthly data for the period spanning from July 1995 to July 2013 to estimate the equations from (1) to (2). Data have been drawn from Handbook of Statistics on Indian Economy and monthly bulletin of RBI and the Economic Database, FRED, maintained by the Federal Reserve Bank of St. Louis of USA. The variables of interest in this study are exchange rate return, the purchases and sales of US dollar by RBI, net FII's, interest rate, inflation rate differentials between Indian and rest of world, and monthly seasonal dummies. Exchange rate return is measured as exchange rates difference between a natural logarithm between two consecutive months using a nominal Rupee/USD exchange rate. The net purchases, purchases and sales of US dollar in rupee billions by RBI are used as intervention's proxies. Other macroeconomic variables are incorporated in order to capture their impact, while examining the

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intervention effect on exchange rate. Interest rate to capture the domestic monetary policy impact by using weighted call money rate as its proxy and inflation rate differential between India based WPI and US based CPI to capture the inflation rate differential effect on exchange rate returns are incorporated in the empirical models. Further, we also include net FII and seasonal monthly dummies so as to observe their effect on exchange rate.

4.1. Methodology

Financial time series such as stock prices, exchange rates are characterized by *volatility clustering or volatility pooling*, i.e., the small changes tend to be followed by the small changes and the large changes tend to be followed by large changes. A simple measure of unconditional variance such as standard deviation does not capture these phenomena of volatilities clustering because it does not take into account time varying volatility. However, autoregressive conditional heteroscedasticity (ARCH) model takes into account the issues related to volatility clustering and incorporate heteroscedasticity in estimation procedure. ARCH model is developed by Engle (1982) and model can be specified as:

$$y_t = \mu + \varepsilon_t \quad (6)$$

$$h_t = \omega + \sum_{t-i}^{p} \alpha_i \varepsilon_{t-i}^2 \quad (7)$$

$$\frac{\varepsilon_t}{\Omega_{t-1}} \sim iid(0, h_t); \omega > 0; \alpha_1, \ldots, \alpha_p \geq 0$$

Equation (6) is the conditional mean equation, where μ is the mean of y_t,ε_t is the error term conditional on the information set Ω_{t-1} and is normally distributed with zero mean and variance h_t. Equation (7) is the variance equation which shows that the conditional variance h_t depends on mean ω and the information about the volatility from previous periods ε_{t-i}^2. The size and significance of α_{t-1} indicates the presence of the ARCH process or volatility clustering in the series. The important aspect of ARCH effect is that ARCH effect presence in the time series yield from the dependency caused by its second movement not from the serial correlation of the error term (linear relationship). This is the reason why the squared errors are included in this model of ARCH process of conditional variance to demonstrate the volatility.

GARCH(1,1)

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Bollerslev (1986) extends the ARCH model for a generalized approach (GARCH), which allows the conditional variance to depend on past sample variances (squared errors), and lagged conditional variances as well. This specification is analogous to the ARMA presentation of times series proposed by Box et al. (1994). This model has two advantages over ARCH, one is that it avoids non-negative constrains and it is more parsimonious because GARCH (1, 1) model with three parameters in the conditional variance equation allows an infinite number of past squared errors to influence the present conditional variance. So, symbolically

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 \, \alpha_i + \sum_{i=1}^{q} \beta_i \, h_{t-i} \qquad (8)$$

In order to ensure that h_t>0, parameters in Equation (8) also need to be bound by the following constraints: α_0>0, α_i>0, and β_i>0, Conditional Variance equation, h_t^2 is the conditional variance because it is a one a period ahead estimate for the variance based on any past information. This conditional variance depends upon a weighted function of a long term average value α_0 and one lagged value of squared residuals $\alpha_i \varepsilon_{t-i}^2$ i.e., information about volatility observed in the previous period and one period lagged value of the conditional variance $\beta_i h_{t-i}$. This means that the conditional variance might not only be affected by the magnitude of innovations and by past values of the conditional variance and for the GARCH process to be stationary, it is necessary that $\alpha_i+\beta_i$ < 1which implies that conditional variance forecasts converges to upon the long term average value of the variance as the prediction horizon increases. Further, one more worth mentioning point here is that if a larger value of GARCH (β_i) parameter, there exists a higher degree of autoregressive persistency in the conditional volatility or long memory and higher impact of error on the conditional volatility. Conversely, if larger value of ARCH(α_i) there exist higher response of conditional volatility to new information.

5. Empirical Results

In this subsection, we present the empirical results of GARCH estimations. Before moving to these results, the descriptive statistics and unit root test results are presented below.

5.1. Descriptive Statistics

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Descriptive statistics the variables are presented in Table 1. This table shows that average (mean) value of Rupee/USD exchange rate returns over the sample period is 0.003. Standard deviation is 0.006 which indicate that exchange rate is dispersed around average value of exchange rate returns. Further, Skewness and kurtosis indicates that exchange rate returns are positively skewed and leptokurtic which indicates the asymmetry in the distribution. Further, Jarque-bera test also indicates that the distribution is non-normality distributed. Average net purchases of US dollar are 24.89 billion rupees per month and its standard deviation is 134.07 billion rupees. This indicates the RBI intervenes, on an average 24.89 billion rupees per month. Average purchases and sales of US dollar are 87.04 and 62.14 billion rupees per month respectively. Similarly, it is also interesting to see that the mean value of purchases is higher than the mean value of sales.

Table 1: Descriptive Statistics

Variable	r_t	np_t	p_t	s_t
Mean	0.0031	24.8969	87.0438	62.1469
Median	0.0007	4.7375	57.0940	38.0661
Maximum	0.0717	536.7569	536.7569	1015.7270
Minimum	-0.0698	-919.2072	0.0000	0.0000
Std. Dev.	0.0204	134.0778	102.4371	101.4905
Skewness	0.3896	-0.9072	2.1262	4.8081
Kurtosis	5.8471	17.2859	8.4506	39.2198
Jarque-Bera	78.7836	1875.0560	432.1212	12697.6300
Probability	0.0000	0.0000	0.0000	0.0000
Observations	217	217	217	217

Note: r_t= exchange rate returns, np_t=Net purchases of US dollar , p_t=Purchases of US dollar, s_t=sales of US dollar

Further, we also observed that during the sample period, RBI intervened around 178 months by purchases of US dollar (82%) and 152 months by sales of US dollar (70%). The relatively high frequent purchases compared to sales indicate that RBI is more concerned about appreciation of the rupee than depreciation of the rupee over sample period. Net purchases are negatively

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skewed while purchases and sales are positively skewed and three variables distributions are leptokurtic. This indicates that all these have asymmetric and excess kurtosis. This is further confirmed by high non-normal distribution with Jarque-Bera values. Hence, all these asymmetries warrant GARCH model to apply in this context.

5.2. Empirical Results:

We estimate the model I using GARCH (1,1) to analyze the effectiveness of intervention on exchange rate level and volatility, and the results are reported in Table 2. The first part of the Table 3.3 shows the conditional mean equation and second part represents conditional volatility equation. In the conditional mean equation, the variable net purchases (np_t) are found to be negative and statistically insignificant. This implies that the level of the exchange rate is not explained by intervention in the foreign exchange market. The insignificance of net purchases may be due to the high foreign exchange turnover compared to size of the intervention. Inoue (2012) argued that RBI intervention in the foreign exchange market become futile to influence Rupee/USD exchange rate due to high foreign exchange market turnover. This finding validates the objective of the RBI, i.e., managing volatility with no fixed rate target. This result is also in line with Unnikrishanan and Mohan (2003).

Similarly, interest rate (ir_t) is also found to be statistically insignificant in explaining exchange rate level. This indicates a weak role played by monetary policy variable in determining the Rupee/USD exchange rate level. However, the variable shows the theoretically explained sign with respect to uncovered interest rate parity theory i.e., higher interest rate in domestic market compared to foreign market leads to an appreciation of domestic currency which implies that higher interest rate in India causes a fall in exchange rate returns. However, inflation rate differential (ird_t) is found to be statistically significant at 1% level and shows expected positive sign. This suggests that a higher inflation in India compared to US leads to a rise in exchange rate returns, which means that Rupee depreciates against the US dollar in the foreign exchange market. This finding is in line with relative purchasing power parity theory.

Finally, net foreign institutional investment inflows (fii_t) is also found to be statistically significant in explaining the exchange rate level at 1% level and exhibits theoretically expected sign. This means that higher FII causes a decrease in the exchange rate returns i.e., it leads to an

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appreciation of rupee against the US dollar. This indicates the role played by net FII inflows in determining the Rupee/USD exchange rate movement in the Indian foreign exchange market. The significance of FII can be attributed to the integration of Indian economy with rest of the world. The capital account liberalization during nineties attracted a high inflow of foreign capital in the form of foreign institutional investments. Further, we also found the significance of five out of eleven monthly seasonal dummies on the exchange rate returns.

Table 2: GARCH Results (Model 1)

Conditional Mean		
Variables	Coefficients	t-statistic
np_t	-4.20E-06	-0.74
ir_t	-6.16E-05	-0.22
ird_t	0.001072	3.12*
fii_t	-0.000145	-12.55*
jan_dum	-0.00524	-1.40
feb_dum	0.003185	0.91
mar_ dum	0.001409	0.43
apr_ dum	-0.005429	-1.92***
ma_ dum	0.015135	6.12*
jun_ dum	0.004047	1.11
jul_ dum	0.003496	0.90
aug_ dum	0.007060	2.05**
sept_ dum	0.011647	4.09*
oct_ dum	0.003802	1.17
nov_ dum	0.015086	5.52*
Conditional Variance		
α_0	3.73E-06	1.56
np_t	-4.17E-08	-2.69***
ARCH(α_1)	0.047550	4.05*

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GARCH(β)	0.919465	42.34*
Log- likelihood=568.2489, SR LB χ^2= 4.4274(0.21) SSR LB χ^2=5.70(0.12) ARCH=0.119(0.11)		

Note: SR-standardized residuals, SSR- standardized squared residual, LB-Ljung–Box statistics for serial correlation at 3 lags. ARCH-LM test for ARCH effects in the residuals respectively.,** and *** indicate the statistical significance at 1%, 5% and 10% level respectively.*

Second part of the Table 2, conditional variance, shows the effect of intervention on exchange rate volatility. The result shows that the variable net purchases (np_t) are found to be statistically significant in explaining volatility at 10% level with negative sign. This indicates that a higher RBI intervention leads to a reduction in exchange rate volatility. This provides a support for effectiveness of intervention in reducing the Rupee/USD exchange rate volatility. Therefore, this confirms that intervention operations of RBI are effective in containing exchange rate volatility of rupee, even though the magnitude of influence does not appear to be very high. This result is consistent with the previous studies such as Unnikrishnan and Mohan (2003), and Behara et al. (2006).

Further, it can also be seen that both ARCH(α_1) and GARCH (β) parameter are found to be statistically significant and consistent to non-negatively constrain. The sum of α_1 and β is 0.96 (0.04+0.94) and this confirms the stationarity of variance and the presence of short memory. Furthermore, the evidence of smaller ARCH effect indicates that the conditional volatility of exchange rate to new information is smaller in the subsequent periods, and larger GARCH effect indicates the high degree of autoregressive persistency or long memory of conditional volatility series.

After the estimation, it is important to verify whether GARCH (1,1) is adequate enough to capture all the dynamic aspects of model or not. The results of Ljung–Box LB test show that the null of serial correlation cannot be rejected in both the cases, i.e., standard and standardized squared residuals, implying that there is no serial correlation in residuals. Similarly, ARCH-LM test also cannot reject the null of no ARCH effect on residuals, implying that there is no further ARCH effect in the model. Log of conditional variance is demonstrated in below Figure 3.

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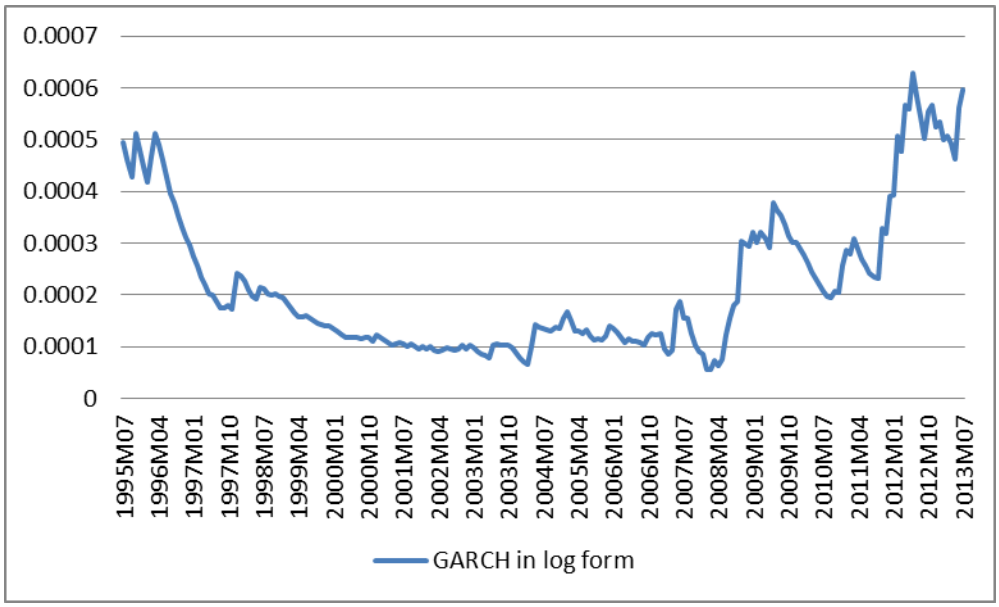

Figure.3

Results of model 2 estimated by GARCH are given in the Table 3. The results show that both purchases (p_t) and sales (s_t) are not statistically significant in the exchange rate level equation. This indicates that neither purchases nor sales of US dollar by the RBI determine Rupee/USD exchange rate in the Indian foreign exchange market. This is consistent with RBI objective of exchange market determined. The positive sign of the variable p_t indicates that the purchases lead to depreciation of the rupee against the US dollar. This provides an evidence for 'leaning against the wind' policy by the RBI during the appreciation of the rupee against the US dollar. Similarly, the variable s_t also exhibits a positive sign in the level equation, which imply that the sales of US dollar by the RBI lead to depreciation of the rupee. This is the indication of the 'leaning with the wind policy' of the RBI during the depreciation of the rupee. These two findings suggest that the RBI does not allow rupee appreciation but allow depreciation against the US dollar through intervention. This also further lends the support for asymmetric intervention by the RBI. We do not present results of other variable in the second model here, since those results are similar to GARCH results with model I in the Table 2.

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Table 3: GARCH Results

Conditional Mean		
Variables	Coefficients	Significance
p_t	2.51E-07	0.03
s_t	9.66E-06	1.11
ir_t	-6.25E-05	-0.20
ifd_t	0.001050	2.76***
fii_t	-0.000143	-12.28*
jan_dum	-0.006016	-1.44
feb_dum	0.002589	0.69
mar_ dum	0.000473	0.12
apr_ dum	-0.006478	-1.88***
ma_ dum	0.014535	5.26*
jun_ dum	0.003487	0.83
jul_ dum	0.002600	0.58
aug_ dum	0.006543	1.68***
sept_ dum	0.011096	3.53**
oct_ dum	0.002917	0.82
nov_ dum	0.014375	4.62*
Conditional Variance		
α_0	4.67E-06	0.83
p_t	-4.83E-08	-2.10**
s_t	6.46E-08	3.14*
ARCH(α_1)	0.046649	3.42*
GARCH(β)	0.916078	30.34*
Log- likelihood=571.3919, SR LB χ^2=4.63(0.20) , SSR LB χ^2= 3.94(0.26), ARCH=1.34(0.25)		

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Note: SR-standardized residuals, SSR- standardized squared residual, LB-Ljung–Box statistics for serial correlation at 3 lags. ARCH-LM test for ARCH effects in the residuals respectively.,** and *** indicate the statistical significance at 1%, 5% and 10% level respectively.*

In the conditional variance equation, purchases (p_t) are statistically significant at 5% level with negative sign whereas sales (s_t) are statistically significant at 1% level with positive sign. This indicates that intervention by purchases reduces exchange rate volatility, whereas intervention by sales increases exchange rate volatility. This supports the evidence of asymmetric impact of intervention on exchange rate volatility. The significant increase in volatility due to sales may be attributed to the lack of credibility of central bank intervention during the depreciation period. Though the RBI attempts to provide direction to market by selling US dollars, but it ultimately prove futile and even increases volatility. This is in line with the findings such as Mckenzie (2002), Guimaraes and Karacadag (2004) in case of Australia and Mexico, respectively. The overall results support that the RBI effectively reduces exchange rate volatility during the appreciation period whereas during the depreciation period intervention accelerates volatility in the market.

6. Conclusion and Policy Implications

This paper analyzes the effectiveness of RBI intervention as well as its asymmetric impact on the Rupee/USD exchange rate level and volatility using monthly data for the period July 1995 to July 2013. This study applies GARCH (1,1) to estimates the intervention effects on the conditional the exchange rata level and volatility. The empirical results with model I where the net purchases of US dollar as a measurement of intervention, shows that RBI intervention is not effective in influencing Rupee/USD exchange rate level and however, it reduces exchange rate volatility implying that RBI is consistent with its stated objective that intervention aims at the exchange rate volatility leaving exchange rate level to market forces. In the results of model 2, RBI intervention does not affect significantly exchange rate level through purchases and sales of US dollar in the conditional GARCH equations. However sign of coefficients suggests that RBI follows a leaning against wind policy during appreciation of the rupee and a leaning with wind

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policy during depreciation of the rupee in the foreign exchange market. Thus, this provides some support for asymmetric intervention by RBI as depreciation allowed but not appreciation. Similarly, in the conditional volatility equations, though purchases reduce exchange rate volatility significantly, sales increases exchange volatility leads to asymmetric effect in the exchange market. Thus, this suggests that RBI is able to reduce exchange rate volatility during appreciation of the rupee successfully rather than depreciation of the rupee against US dollar in the foreign exchange market. The sales are less credible as RBI committed to depreciation rupee leads to uncertainty in the foreign exchange market. This implies that RBI should implement the policies which enhance credibility over sale intervention during depreciation of rupee. This study has two limitations. One, it uses the monthly data with which one is unable to extract all dynamics of exchange rate variances as unavailable data on intervention at higher frequencies level such as day and intraday basis. Second, asymmetric effect of intervention can be further studied effectively with advance technique such EGARCH and TGARCH.

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