THE EFFECTIVENESS OF CENTRAL BANK INTERVENTION IN THE FOREIGN EXCHANGE MARKET: EVIDENCE FROM INDIA

A Thesis submitted in partial fulfilment of

requirements for the degree of

MASTER OF PHILOSOPHY IN ECONOMICS

by

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to the

DEPARTMENT OF LIBERAL ARTS

INDIAN INSTITUTE OF TECHNOLOGY HYDERABAD

APRIL 2014

DECLARATION

I declare that this thesis represents my own ideas and words and where others ideas or words have been included; I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented, fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will result in disciplinary action by the Institute and can also evoke penal action from the sources that have not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE

It is certified that the work contained in the thesis entitled "Effectiveness Of Central Bank Intervention In The Foreign Exchange Market: Evidence From India " submitted by Topunuru Kaldhar (LA12M1006) in partial fulfillment of the degree of Master of Philosophy to the Department of Liberal Arts, Indian Institute of Technology Hyderabad, is a record of bonafide research work carried out by him under my supervision and guidance. The results embodied in the thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

CERTIFICATE

This is to certify that Topunuru Kaladhar (LA12M1006) has satisfactorily completed all the course requirements for the M.Phil.Program in Economics. Topunuru Kaladhar was admitted to the candidacy of the M.Phil. degree in August 2012 .

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Kaladhar. T

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ABSTRACT

This thesis empirically analyzes the effectiveness of RBI intervention in the foreign exchange market. The study framed two objectives related to the central bank intervention. The first objective deals with analyzing the effectiveness of RBI intervention on exchange rate level and volatility. And the second deals with the relevance of asymmetric intervention on exchange rate level and volatility. Using monthly data from July 1995 to July 2013 and GARCH methodology, the thesis empirically estimates two models. First model estimates the effect intervention on the exchange rate level and volatility by measuring intervention as net purchases of US dollar by the RBI. In second model included both purchases and sales of US dollar as a proxy the intervention to analyze the effect of asymmetric intervention on exchange rate level and volatility. The empirical findings suggest that the RBI intervention is not effective in influencing the level of Rupee/USD exchange rate. However, the study found that the RBI intervention is effective in reducing the volatility. The empirical findings also show that intervention by purchase of USD by RBI significantly reduces volatility whereas intervention by sales significantly increases volatility in exchange rate. These findings confirm the asymmetric effect of intervention in exchange rate volatility in the Indian context.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION: Historical perspective of central bank intervention and its relevance

Over the last four decades, there has been a tremendous change that took place in the international economic scenario, especially after the mid-seventies when most of the countries moved from fixed exchange rate to floating exchange rate system. Since then, the major developed countries experienced high exchange rate volatility due to speculative attacks (Sarno and Taylor, 2001). Consequently, most of central banks in these countries started intervening in the foreign exchange market to mitigate the exchange rate volatilities. Thus, central bank intervention in the foreign exchange market has emerged as an inevitable and essential tool to curtail the exchange rate risk. In particular, developed countries like Japan, Canada, Germany, US and European countries started intervening in the foreign exchange market when it is necessary to influence the exchange rate in order to curtail uncertainties in the foreign exchange market.

More interestingly, the central banks in developing countries also started intervening in the foreign exchange rate market since eighties. This is the period in which most of these countries initiated policies of financial integration and undergone exchange rate risk due to high capital flows. Therefore, it is hardly observed that any exchange rate system where the exchange rate is completely determined by demand and supply in the context of developing countries. Calvo and Reinhart (2002) states "*most of exchange rate regime describes as freely floating under the IMF classification, are actually characterized by*

heavy exchange rate management by the respective authorities". Moreover, developing countries view intervention as an effective tool to mitigate adverse effects of the exchange rate overvaluation on export competitiveness arising out of short term capital inflows.

Figure 1.1 shows the trends in foreign exchange reserves with emerging countries where the reserve holdings can be considered as one of the indicators and the outcome of the central bank intervention[1]. It can be seen that most of the countries like Brazil, China, India, Russia, Korea, Singapore, Thailand, Turkey and Mexico accumulated huge level of reserves by the end of 2013. This is the clear indication that these countries are actively intervening in the foreign exchange market. Malloy (2013) argues that central bank intervention in emerging economies is conducted for purpose of protection of export competitiveness, smoothing short term volatility. This leads to the accumulation of huge reserves. In particular, India has also accumulated with about 293 billion US dollars as reserves by 2013.

1.2 CENTRAL BANK INTERVENTION: Definition

Neely (2005) defines central bank intervention as a practice of monetary authorities of buying and selling currency in the foreign exchange market to influence exchange rates. In other words, the central bank tends to buy or sell the foreign currency in the foreign exchange market to produce the artificial demand and supply in order to influence exchange rate and volatility.

[1]Due to the lack of availability of data on purchase of foreign currencies by the central banks of some of these countries, we show the trends in reserves holding as a proxy for intervention.

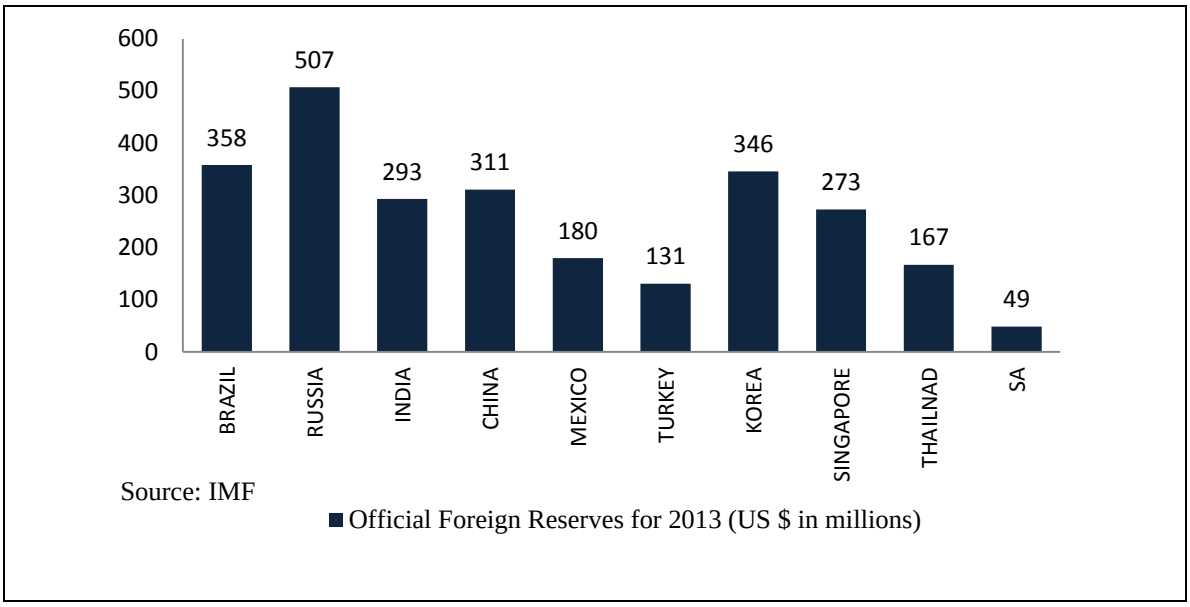

Figure 1.1: Trends in Reserve Holding with Emerging Economies

1.2.1 Objectives of central bank intervention:

The central banks pursue intervention with specific targets and objectives to influence exchange rate in the foreign exchange market. The main motives behind the central bank interventions are discussed below[2].

(i) Correct the misalignment or stabilize the exchange rate at pre-determined level

One of the main objectives of the intervention is to correct the exchange rate misalignment or stabilize the exchange rate at pre-determined level. This is mainly to avoid the adverse effect of exchange rate overvaluation or undervaluation on the performance of the economy. The central bank intervenes when exchange rate is overvalued to mitigate its adverse effect on countries' export competitiveness. Similarly, central banks also intervene to avoid the inflationary pressure on economy, when

[2] For more information on motives of intervention , see Canales-Kriljenko et al. (2003)

exchange rate is undervalued. Calvo and Reinhart (2002) argues that stronger pass-through of exchange rate fluctuations to inflation and huge exchange rate volatility leads to unavoidable policy of intervention of foreign exchange market

(ii) Calm disorderly market, including exchange rate volatility and market liquidity:

Central bank intervention serves as an instrument to smooth volatility and disorderly market conditions in the foreign exchange market. Particularly in the case of developing countries, central banks intervene to moderate the changes in the exchange rates, unwarranted high volatility, a widening of bid-offer spreads and drastic changes in market turnover which arises due to the market illiquidity.

(iii) Reserves Accumulation:

Central banks intervene to accumulate foreign exchange reserves. Central banks accumulate foreign exchange reserves through intervention in order to insure future unpredictable uncertainty and confidence among foreign investors about the economy and strengthen their debt repayment capacity and external liquidity position.

(iv) Supply of foreign exchange to the market:

Central banks intervene in the foreign market to ensure supply of foreign currencies. Since central banks in the developing countries serves as an agent to public sector and state enterprises (SOE) which account for huge foreign currency earning through exports. The public and state enterprises lack the skilled personnel to manage operations relating

to foreign currency assets and liabilities, including the timing of their foreign exchange purchases and sales in the foreign exchange market.

Moreover, IMF also stipulates certain guidelines for intervention in the foreign exchange market for its member countries.

1. *A member shall avoid manipulating exchange rates or the international monetary system in order to prevent effective balance of payments adjustment or to gain an unfair competitive advantage over other members.*

2. A member should intervene in the foreign exchange market, if necessary, to counter disorderly conditions which may be characterized inter alia by disruptive short-term movements in the exchange value of its currency.

3. Members should take into account in their intervention policies the interests of other members, including those of the countries in whose currencies they intervene.

1.2.2 Kinds of intervention

Central bank intervention can be classified as four categories:

1. Coordinated vs. Unilateral intervention:

Coordinated intervention occurs when the two or more central banks of different countries intervene simultaneously in foreign exchange market to influence the exchange rate movement according to agreement among those countries (Sarno and Taylor, 2001). While unilateral intervention involves only single central bank in this transaction,

coordinated intervention is to improve the effectiveness of intervention. For example, in the Louvre Accord agreement, Bank of Japan, Bundesbank and Federal Reserve of US were coordinated to intervene in order to curb an appreciation of US dollars and exchange rate volatility during 1987 to 1991(Bonser-Neal and Tanner, 1996 and Dominguez, 1998).

2. Secret vs. Reported intervention:

Central bank intervention can be secret or reported depending on the circumstances and objectives of the moment. Transparency of intervention is required to transmit impact of intervention on the exchange rate through channels such as the signaling and coordination channels, to minimize the noise created by policy uncertainty and consistency with other elements of public policy and for accountability. Whereas secret intervention is used to minimize the impact of intervention when the central bank does not want to intervene but is forced to do so by authorities; when intervention is inconsistent with other policies; when the central bank is uncertain about its objectives to achieve. Neely (2005) argued that 77 percent of interventions by central banks across the world were secret intervention.

1.3 CENTRAL BANK INTERVENTION IN INDIA

The intervention by the Reserve Bank of India (RBI), the central bank of India, is very active in intervening in the foreign exchange market especially after the economic reforms that initiated in the early nineties. As part of reforms, India moved from fixed exchange rate system to the Liberalized Exchange Rate Management System, in March

1992, which involves dual exchange rate system where exchange rate is determined by both RBI and market forces partly (Reddy, 1999). However, the dual exchange rate system has turned into a market determined foreign exchange rate system in March 1, 1993 in which exchange rate is determined fully by market forces of demand and supply. RBI (2008a) states "*India is classified under the 'managed float' exchange rate regime of the IMF. The Reserve Bank intervenes in the foreign exchange market to contain excessive volatility as and when necessary*[3]." This indicates that the RBI follows managed floating policy by intervening in the market from time to time when it is necessary. Another worth noting point here is RBI is intervening with no public notice, i.e. the intervention in the foreign exchange market is secret or confidential.

Baig et al. (2003) argues that with convertibility on current account and partial capital account, dismantling administrated interest rates, easing the capital inflows measures, inflows of foreign capital and the size of market turnover increased in manifolds during 1990's. The average daily turnover in Indian foreign exchange market has grown from USD 3.0 billion in 2001 to USD 34 billion in 2007 asserting it as the fastest growing market in the world (BIS, 2007). Similarly, the surge in capital flows also increased uncertainties in the foreign exchange market. Hence, the interventions by the RBI become inevitable in in the foreign exchange market.

1.3.1 Objectives of central bank intervention in India (RBI)

The major policy objectives of intervention stated by Reddy (1997) are as follows:

[3] *Annual Report (Reserve Bank of India, 2008a, p. 127)*

1. To dampen excessive volatility of exchange rates and ensure the adjustments of over and undervalued exchange rate with no fixed rate target. This allows the underlying demand and supply condition to determine the exchange rate movements in the foreign exchange market.
2. To accumulate an adequate level of foreign exchange reserves.
3. To eliminate market constraints in order to develop a healthy foreign exchange market.

The above objectives indicate that RBI intervenes to curtail excess volatility without affecting exchange rate level, prevent the destabilizing activities, accumulate adequate exchange rate reserves and develop orderly foreign exchange market.

1.3.2 Reserve bank of India intervention trends

The RBI uses various combinations of techniques in intervening in the foreign exchange market such as direct action by purchases and sales of foreign currency in the spot, forward and swap markets and indirect action by press statements (Ghosh, 2002). Figure 1.2 shows the trends in net purchases of US dollar by RBI along with Rupee/USD exchange rate for the period 1995-2013. The trend in net purchases of US dollar suggests that the RBI actively intervene in the foreign exchange market during this period. It is interesting to see that the number of positive net purchases of US dollars is more than number of negative net purchases of the US dollars. This indicates that the RBI intervening by purchasing US dollars most of the periods compared to sales to reduce the volatility of Rupee/USD exchange rate. Furthermore, it can also be argued that higher net purchases of US dollar may be able to stop the appreciation of Rupee against US dollar.

However, after 2008 it can be seen that there is a high negative net purchases of US dollar, i.e., the RBI became a net seller of US dollars, to prevent rupee deprecation in the foreign exchange market.

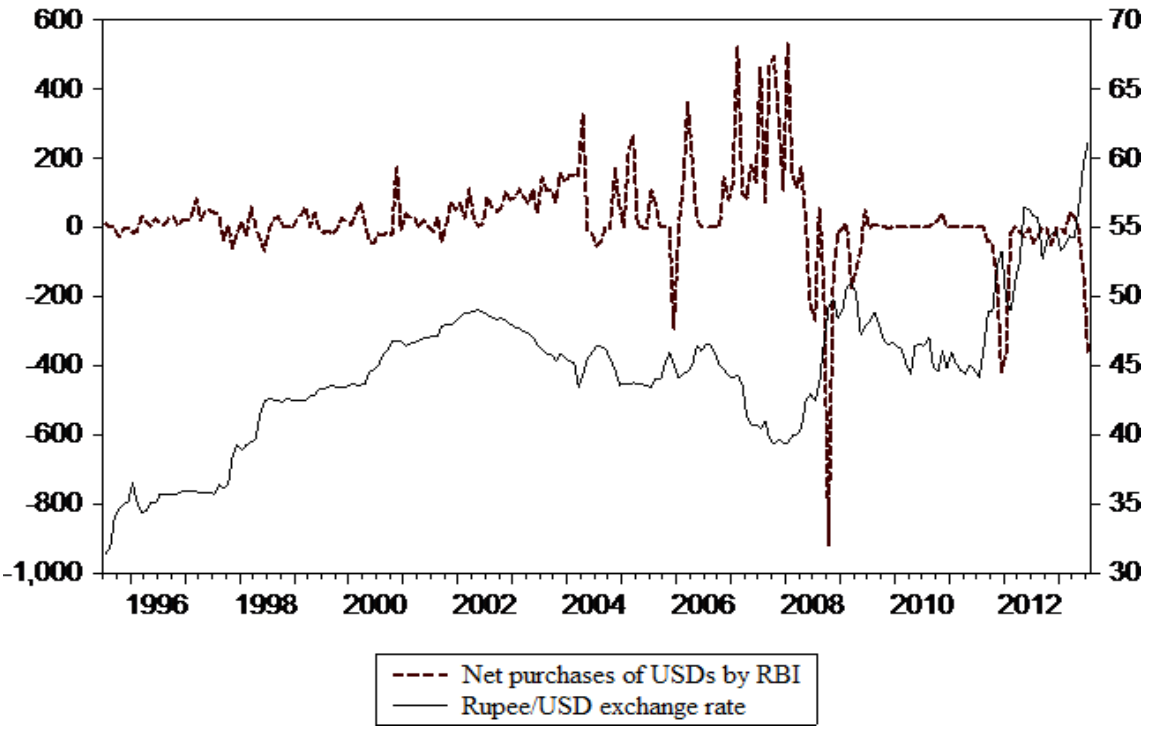

Figure 1.2: Trends in Net Purchases of US dollar by RBI and exchange rate

Figure 1.2 shows the trends in foreign exchange reserves in India and it shows that the 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.

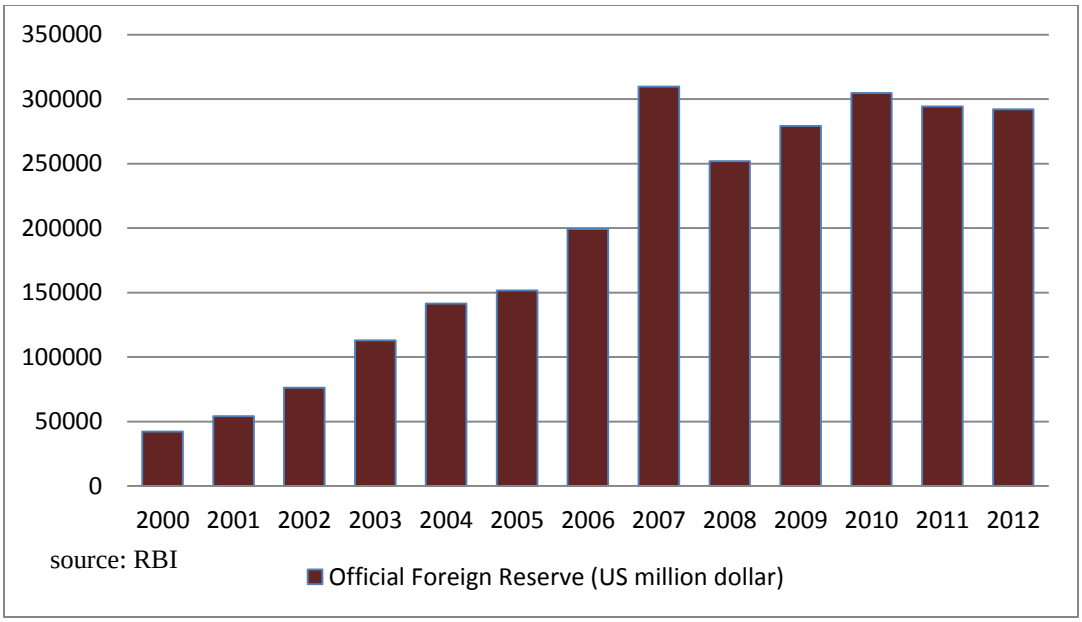

Figure: 1.3 India Intervention Trends

1.4 Research Issues:

Given the evidence of frequent intervention by the RBI in the foreign exchange market, the present study analyzes the effectiveness of RBI interventions. The study addresses two issues. First, the effectiveness of RBI intervention on the Rupee/USD exchange rate level and volatility. Second, the study analyzes the aspect of asymmetric impact of intervention on the exchange rate level and volatility in the Indian context.

1.5 Organization of thesis:

This following thesis is organized as follows: Chapter 2 discusses the theoretical and empirical literature of central bank intervention. Chapter 3 deals with the empirical model, methodology and empirical analysis. Chapter 4 summarizes the major findings and concludes.

CHAPTATER II

REVIEW OF LITERATURE

2.1 INTRODUCTION:

We can find plenty of empirical literature on the central bank intervention in the international finance area. However, it is difficult to summarize all of those literature and works. Some relevant studies and literature is presented in this chapter, in particular, theoretical background of central bank intervention and empirical literature on the exchange rate level and volatility. This chapter is organized as follows: Section 2.2 deals with theoretical background of central bank intervention which includes mechanics of intervention and channel of influence; section 2.3 reviews works on the effectiveness of central bank intervention on the exchange rate level and volatility in the international and Indian context as well as asymmetric impact of intervention on the exchange rate and section 2.4 highlights the research gap which set ground for the present study. Section 2.5 presents objective of the study. As mentioned in the definition and kinds of intervention of central bank in the introduction chapter, the same is included in the theoretical background part of this chapter.

2.2 THE MECHANICS OF CENTRAL BANK INTERVENTION:

To understand the mechanics of central bank intervention in foreign exchange market, it is necessary to analyze monetary side of the economy. Monetary base (M) of an economy consists of two components i.e., Net Foreign Assets (NFA) and Domestic Credit (DC);

where DC is defined as net domestic assets minus net worth, which represents the stock of domestic credit that is available to the monetary authorities. Symbolically, it can be described as:

$$M = NFA + DC \quad (2.1)$$

where any change in NFA or DC will have a proportionate change in monetary base. When central bank intervenes in the foreign exchange market, NFA will change and thereby change in the monetary base. Based on the change in monetary base, the central bank intervention can be classified as sterilized and non- sterilized.

Sterilized intervention:

Central bank intervention is said to be sterilized, when a change in NFA does not lead to any change in the monetary base. In other words, sterilized intervention by central banks refers to the actions taken to offset or to counter the effects of a change in NFA on domestic monetary base by conducting open market operations (Sarno and Taylor, 2001). Thus, above monetary equation 2.1 will be:

$$\Delta M = \Delta NFA + \Delta DC = 0 \quad (2.2)$$

Non-sterilized Intervention:

Central bank intervention is said to be non-sterilized, where central banks or authorities buy or sell foreign currency, without the intentions of offsetting the changes in NFA , thereby, resulting into direct effect on monetary base. In other words, central banks do

not conduct open market operations to sterilize the expansionary or contractionary effect of change in NFA on M. (Sarno and Taylor, 2001).

$$\Delta M = \Delta NFA + \Delta DC \neq 0 \qquad (2.3)$$

The central bank intervention influences the exchange rate and this can be explained through different channels.

2.2.1 Channels of influences:

The effect of central bank intervention on exchange rate is operated through four types of channels.

Monetary channel:

This channel is related to non–sterilized intervention. Central banks' purchases or sales of foreign currency against domestic currency affects the exchange rate through changes in relative money supplies of domestic and foreign countries and thereby interest rate (Brissimis and Chionis, 2004).

Portfolio balance channel:

This portfolio channel is related to sterilized intervention. When domestic and foreign assets are imperfect substitutes, central bank intervention changes the relative supplies of domestic and foreign assets or bonds. This leads agents to rebalance their portfolios so that they can equalize risk-adjusted returns, which then affects the exchange rate in the foreign exchange market (Guimaraes and Karacadag, 2004).

Signaling channel:

Under this channel, intervention can be effective if it is perceived as a signal of the future monetary policy stance. As per this channel, even if the domestic and foreign assets being perfect substitutes, intervention influences expectations about future monetary policy and that leads to change in the exchange rate (Mussa, 1981). For this channel, central bank intervention must be announced.

Micro structure or Order flow channel:

In micro structure or order flow channel, where buying or selling transaction of foreign currency of central bank larger in the magnitude compared to foreign exchange market turnover, intervention affects exchange rate by passing the information to market through its negative and positive order flows in the foreign exchange market (Disyatat and Galati, 2007). For this, intervention can be either announced or unannounced.

2.3 EMPIRICAL LITERATURE

Most of the empirical studies in this context deal with how central bank intervention in the foreign exchange market affects exchange rate level and volatility. The effectiveness of central bank intervention is evaluated by analyzing its impact on the exchange rate level and volatility. 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). In case of developing countries, the literature shows that the intervention is effective in influencing exchange rate level and volatility because central bank is a dominant player in foreign exchange rate market (Canales-Kriljenko et al., 2003) whereas in the context of developed countries, it shows a mixed evidence (Disyatat and Gilati, 2007).

To analyze the effectiveness of central bank intervention on the exchange rate level and volatility, most of the studies estimate the following equations.

$$r_t = int_t + z_t \tag{2.4}$$

$$h_t = int_t + z_t \tag{2.5}$$

Where equation (2.4) represents exchange rate level (mean equation) and equation (2.5) represents exchange rate volatility equation. Where *r* represents, a change in exchange rate (exchange rate returns), *h* denotes a change in exchange rate volatility, *int* denotes central bank intervention in foreign exchange market, *z* denotes other variables that determine exchange rate which includes money supply, interest rate differentials, capital inflows, news on the exchange rate policy, intervention dummy and *t* denotes time etc.

2.3.1 Central bank intervention, exchange rate level and volatility: Empirical literature:

The issue related to effectiveness of central bank intervention gains attention in the empirical literature especially after the mid of 1980's. During this period, most of the countries started adopting flexible exchange rate policies and hence experienced high

volatility in exchange rate. For instance, during 1985-1991, the Federal Reserve of US (FED), Bundesbank of Germany and Bank of Japan (BOJ) intervened in the foreign exchange market in various form in order to curtail the US dollar appreciation against the non US dollar currencies and exchange rate volatility. Therefore, this period has an immense importance for the central bank intervention in advanced and developed nations. Further, this period can be split into two sub periods. First, the Plaza agreement period (1985-1987), intervention was coordinated among the above three nations, to ensure an orderly appreciation of main non-dollar currencies against the US dollar. Second, the Louvre Accord period (1987-1991), these nations were coordinated in order to foster stability of exchange rate of US dollar against non-US dollar currencies (Bonser-Neal and Tanner, 1996).

In this section, we discuss different issues that addressed in the literature, such as the effectiveness of secret and publicly known intervention; impact of size and duration of intervention; impact of asymmetric intervention on the exchange rate level and literature related to the Indian context.

Bonser –Neal and Tonner (1996) analyze the impact of coordinated intervention by above three central banks on the exchange rate volatility of Dollar/Dutch Mark and Dollar/JPY for the sample period 1985-1991. This study employs an implied volatility method[4] which is based on currency option prices, to derive the exchange rate volatility. It is found that intervention is associated with a positive or no change in the exchange rate volatility in coordinated intervention period 1985-1991. However, in the sub-sample

[4] 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 and Nydahl 2000).

analysis, during 1985-87 (the Plaza agreement period) the study found that the Fed intervention reduces USD/DM volatility; however the interventions by Bundesbank and BOJ do not have any impact on the USD/DM and USD/JPY volatility. During the Louvre Accord period (1987-91), the interventions by Fed and BOJ increase USD/DM and USD/JPY volatility and Bundesbank intervention has no impact on exchange volatility. This study also finds that macroeconomic announcement leads to a decline in exchange rate volatility and macroeconomic surprise leads to a rise in exchange rate volatility. Similarly, stock market volatility also leads to a rise in exchange rate volatility.

Dominguez (1998) examines the impact of central bank intervention on exchange rate volatility for period 1977 - 1994 in the case of Fed, Bundesbank and BOJ. Unlike previous studies, the author compared that relative impact of secret and publicly known intervention on exchange rate. They test two hypotheses; one, secret intervention which is ambiguous, non-credible signal, leads to increase in uncertainty thereby volatility. Second, reported intervention which is unambiguous and credible signal leads to no impact on volatility or possibly reduces exchange rate volatility. They use GARCH and implied volatility methods. The empirical results show that reported intervention reduces exchange rate volatility while secret intervention increases exchange rate volatility. This study concludes that reported or publicly known interventions with unambiguous signals are more potent in curtailing exchange rate volatility. Further, this study also shows that results are sensitive to methodology applied. Evidence can be seen in the case of Bundesbank where intervention is found to be associated with a fall in exchange rate volatility by applying GARCH model while it is associated with a rise of exchange rate volatility in the implied volatility method. This study also shows that news about

exchange rate policy decreases exchange rate volatility. Similarly, a dummy which captures holiday effect increases the exchange rate volatility. Finally, interest rate spread also increases the exchange rate USD/DM volatility and decreases USD/JPY volatility.

Bein et al. (2003) studied the impact of coordinated intervention by above three central banks for the period 1985-1995. Unlike the previous studies, the study analyzed whether there is any difference in the impact of intervention with respect to the periods of high and low volatility. Using the Markov switching model, the study finds that intervention leads to a stabilizing effect when the market is more volatile and intervention is unambiguously expected whereas central bank intervention leads to destabilizing effect on the exchange rate volatility when market is less volatile and intervention is more ambiguous. This study also corroborates that coordinated intervention is more effective than unilateral intervention.

Nagayasu (2004) examines the impact of coordinated intervention of Bank of Japan with Federal Reserve on the JPY/USD exchange rate level and volatility during the period 1991 to 2001. Using GARCH model, this study finds that unilateral intervention does not have any impact on the JPY/USD level alone. Conversely, when there is intervention coordinated with Fed, intervention is found to have a significant impact on exchange rate, where intervention significantly reverses the direction of exchange rate.

Brissmis and Chionies (2004) analyzed the relative impact of publicly known intervention by European Central bank to influence the USD and secret intervention by Bank of Japan to influence Euro, for the period 1999-2001. Using GARCH Model, the study found that secret intervention by BOJ increases the exchange rate level and

volatility of JPY/USD exchange rate whereas publicly known intervention does not have any impact on both exchange rate level and volatility. This also affirms that secret intervention is more potent than publicly known intervention in influencing exchange rate. Further, this study also finds that neither interest rate differentials nor Monday effect are found to be significant in determining the exchange rate.

Aguilar and Nydahl (2000) examine the effect of intervention of Swedish central bank, Risk Bank, on the level and volatility of the SEK/USD and SEK/DEM exchange for the period 1993 - 1996. Using GARCH and implied volatility methods, the study finds that intervention leads to depreciation of Swedish krona, however the extent of impact is less or marginal. Further, intervention is not found to have impact on the exchange rate volatility. Moreover, the study sheds some light on spillover effect[5] from the SEK/USD exchange rate to SEK/DEM exchange rate. In sub sample period analysis, intervention is found to have mixed impact on the exchange rate level and volatility. Overall, the study provides weak evidence for the effectiveness of intervention on the level of exchange rate and support for reduction in exchange rate volatility.

Unlike above studies, few authors analyzed the effect of intervention on exchange rate in terms of size of the intervention; economic significance of intervention; duration of intervention; the issues related to public announcement of the monetary and fiscal policies on intervention. Disyatat and Galati (2007) analyze the impact of intervention of Czech National Bank (CNB) on the koruna/euro exchange rate for the period of September 2001- October 2002 using the instrument variables method. This study tested

[5] Spillover effect means how changes in one exchange rate can have impact on the other exchanger rate (Aguilar & Nydahl, 2000).

the impact of intervention on the spot exchange rate, implied volatility and risk reversal. The empirical results show that there is no effect of contemporaneous intervention on the exchange rate. Whereas the study found a significant impact on exchange rate based on cumulative sum of current and lagged intervention. Similarly, the contemporaneous and cumulative intervention is found to be ineffective in implied volatility model and further, it finds that cumulative intervention has an impact on the risk reversal, which shows the effect on market participant's balance of weight between a stronger and weaker koruna. This study provides a support that effect of intervention is low and very small in economic terms and moreover, portfolio balance and macro structure channel may be operational effectively in the emerging countries since CNB intervention size is larger relative to foreign exchange market. Furthermore, this study concludes that CNB seems to have intervened in response to the speed of koruna appreciation against euro in order to decelerate the speed of koruna appreciation against euro, following results of intervention reaction function.

Galati et al. (2005) analyze the impact of Bank of Japan intervention on the JPY/USD exchange rate during the period 1993 - 1996 employing instrument variable method. In this study, intervention is found to be ineffective to influence the level of exchange rate. However, intervention destabilizes exchange rate volatility in the foreign exchange market. This study also finds that BOJ intervenes with respect to the deviations of the exchange rate from some implicit target range, to reduce exchange rate uncertainty. Furthermore, this study suggests that intervention with no coordination and public announcement has a less lasting effect on the exchange rate movements.

Few studies use event analysis to capture the effect of duration of intervention and to find the effect of monetary policies along with intervention on the exchange rate. Event analysis method is better suited when the study of sporadic and intense periods of central bank intervention than standard time series method (Futum and Hutchison, 2003). This method defines three different criteria to evaluate the success of intervention. Firstly, the direction criterion which is defined as exchange rate movements which are coincided with a direction of intervention desired during post window. Secondly, a smoothing criterion which is defined as a change in movement of exchange rate compared to pre-window after intervention event has occurred. Thirdly, reversed success criterian, which is defined as the change in ongoing trend that occurs in post window with intervention.

Futum and Hutchison (2003) analyze the effectiveness of central bank intervention on DM/USD exchange rate for period 1985-1995 using event analysis method. This study concludes that Bundesbank intervention is found to be successful based on above mentioned criteria. This indicates that intervention plays a major role in determining exchange rate in terms of its movements, smoothing and reversing the direction of ongoing movements. Further, this study also provides the evidence of leaning against the wind policy of central bank. This study also finds that there is no long run effect of intervention on the exchange rate movements. Furthermore, interventions combined with interest rate changes are found to have higher impact compared to interventions without changes in interest rate.

Fatum (2008) also analyzes the effectiveness of intervention of Bank of Canada using event analysis method for the period 1995-1998. This study analyses how discretionary

and mechanistic interventions have different impact on the movement of CAD/USD exchange rate by considering the issue of currency co-movements. The empirical evidence shows that Bank of Canada intervention is found to be effective in changing the movements of exchange rate and bringing smoothness in the movement of exchange rate. However, the evidence shows that intervention become weaker after taking into the consideration the currency co-movement against US dollar in the foreign exchange market. Moreover, it also found that discretionary interventions are more potent than mechanistic interventions.

Unlike other studies, Simwaka and Mkandawire (2012) examine Reserve Bank of Malawi (RBM) intervention on Kwacha/USD exchange rate for the period 1995-2008. The main focus of the study is to test whether central bank intervention is effective in minimizing the deviation of actual exchange rate from its equilibrium exchange rate. Using Edward's (1989) dynamic model for a real exchange rate, the equilibrium exchange rate is estimated and the deviation of actual exchange rate from equilibrium exchange rate is measured. Using GARCH method, they analyzed the effect of intervention on the exchange rate deviation. The results show that central bank intervention does not help to bring back the exchange rate to its equilibrium levels except for the period 2003. GARCH results also show that RBM intervention (net sale of foreign currency) is found to be associated with depreciation of the Kwacha. However, during the post 2003 period, intervention leads to appreciation of the exchange rate. Further, it also finds that intervention leads to a rise in exchange rate volatility in the foreign exchange market. The study also found that a higher inflation rate differential as well as a higher exchange rate premium also leads to depreciation of exchange rate.

Edison (2003) analyzes the effectiveness of Reserve Bank of Australia (RBA) on AUD/USD exchange rate level using event analysis method and GARCH for the period January 1984 to December 2001. An event analysis result suggests that RBA follows leaning against the wind policy when its currency depreciates. GARCH results suggest that RBA intervention is ineffective in moderating the exchange rate movements. It is also found that RBA intervention increases the exchange rate volatility.

Some studies used the high frequency data, like intraday data, to analyses the effect of intervention on exchange rate as well as examining the simultaneous effect of other variables, such as news on exchange rate policy and monetary policy. Chang and Taylor (1998) examine the effectiveness of intervention of BOJ on exchange rate using intraday data from October1992 to September 1993 using GARCH model. This study primarily examines whether there is any equality in variance of exchange rate or not. And the empirical findings suggest that the JPY/USD exchange rate volatility is varied across period from one hour before and after the central bank intervention. The results also shows that intervention is associated with high exchange rate volatility especially after 5 to10 minutes intervals of intervention.

2.3.2 Asymmetric impact of central bank intervention on the exchange rate level and volatility:

Some of the recent and notable studies analyze the asymmetric impact of central bank intervention on the exchange rate level and volatility in the foreign exchange market. Instead of taking net purchases of foreign currency as a measure of intervention, these studies took purchases and sales of foreign currency separately to test impact of

intervention. Asymmetric effect implies that the purchases and sales have different impact on the exchange rate level and volatility. In general, central bank intervenes by purchasing foreign currency during the appreciation of domestic currency and by selling foreign currency during the depreciation of domestic currency to moderate the appreciation and depreciation respectively. This intervention is referred as 'leaning against the wind policy' i.e., central bank intervenes to slow or reverse the ongoing trend. Some cases, the central bank support the ongoing trend of exchange rate, for instance, allowing depreciation during capital outflows to improve export competitiveness. This type of intervention is referred as 'leaning with the wind policy'. It is mainly because the central bank has different preferences towards depreciation and appreciation of the domestic currency. For instance, the central bank may follow a stronger leaning against the wind policy during periods of appreciation than during depreciation. It is found that this asymmetric intervention in emerging market is strong, i.e., interventions in emerging countries generally appear lenient with regard to depreciation of the domestic currency but strict concerning its appreciation (Adler and Tovar, 2011).

One of the main reasons for this asymmetric intervention is attributed to 'fear of floating', which suggests that the emerging economies are reluctant to float their currencies due to the fear of depreciation i.e., a large degree of depreciation, may lead to financial crisis (Calvo and Reinhart, 2002). In contrast, fear of appreciation arises as a result of short term financial inflows. The larger appreciation of exchange rate may harm exports, current account and economic growth (Kappler et al. 2011; Levy-Yeyati et al., 2012; Bussiere et al., 2013).

Frenkel et al. (2004) investigate the impact of Bank of Japan intervention of sales and purchases in the foreign exchange market for the period 1993-2000. In the results, it is found that purchases of foreign currency are associated with a rise of exchange rate volatility whereas sales of foreign currency are associated with no impact on exchange rate volatility. This indicates that intervention through purchases result in destabilizing foreign exchange market compared to sales. Unlike other studies, this study includes dummy variables to captures the presence of intervention and volume of intervention and found that the presence of intervention is significant in explaining volatility of exchange rate.

Guimaraiesa and Karacadag (2004) analyze the asymmetric effect of intervention on the exchange rate level and volatility in case of Mexico and Turkey, for the period August 1996-June 2003. This study uses the Asymmetric Component Threshold GARCH model in order to analyze intervention impact on both long and short time horizon simultaneously. In the case of Mexico, the empirical findings show that, interventions by sales leads to appreciation of exchange rate whereas intervention by purchases leads to no significant impact on the exchange rate. This indicates that sales have more effect in influencing exchange rate level than purchases. Similarly, in the case of volatility, it is found that sales increases uncertainty compared to purchases in both long and short time horizons. In the case of Turkey, both sales and purchases, does not influence the exchange rate level. Similarly, in the case of volatility, the sales and purchases are associated with a fall of exchange rate volatility.

Mckenzie (2002) examines the asymmetric impact of Reserve Bank of Australia (RBA) intervention on the USD/AUD volatility applying GARCH and TGARCH (Threshold GARCH) model, using daily data period covered from 12 December 1983 to 31 December 1997. The GARCH result show that sales by RBA during the periods of depreciation of the Australian dollar increase exchange rate volatility compared to purchases during the period of appreciation. This confirms that the intervention during the time of negative shock (depreciation) leads to high volatility compared to intervention during the positive shock (appreciation). This confirms the asymmetric intervention by the RBA. The results are further confirmed by TGARCH model.

Lahura and Vega (2013) analyze the asymmetric effect of central bank intervention in the case of Peru using intraday data for the period January 5, 2009 to April 27, 2011. This study uses two methodologies, structural vector autoregressive model (SVAR) and event study analysis. Both event and SVAR results suggest that intervention through sales are more effective to influence exchange rate compared to purchases.

Domac and Mendoza (2004) examine the asymmetric effect of central bank intervention on exchange rate in context of Turkey for the period 1996-2001 and Mexico for the period 2001- 2002. This study uses the Exponential GARCH model and compares the impact of net sales, sales and purchases on exchange rate level and volatility to analyze the asymmetric effect. The empirical results show that the net sales of US dollars leads to appreciation of exchange rate. Further, intervention by sales leads to appreciation of exchange rate, while purchases do not lead to depreciation of the exchange rate, in the case of both countries. In case of volatility of exchange rate, the overall central bank

intervention (net sales of foreign currency) is associated with reduction in exchange rate volatility in both the case of Turkey and Mexico. Whereas, intervention by sales are associated with a reduction in exchange rate volatility compared to purchases. This confirms that asymmetric effect of central bank intervention on the exchange rate. Further, the results also show that the monetary policy instrument, i.e., interest rate, is significantly reducing the exchange rate volatility in case of Turkey. Moreover, EGARCH effect further confirms that there is a leverage effect in case of Mexico but not in Turkey. This means that bad news or negative shock (depreciation) causes more volatility in the Mexico foreign exchange market.

Broto (2012) analyses the asymmetric impact of four central bank intervention in case of Chile, Colombia, Mexico and Peru on the exchange rate volatility using GARCH model for the period July 1996- Jun 2011. This study shows that there is asymmetric effect of intervention on the conditional variance of exchange rate where purchases and sales of US dollar dominates on the exchange rate volatility dynamics and help to stabilize it. For instance in the case of Peru, purchases lead to reduction in volatility while in the case of Columbia, purchases lead to increased volatility.

By having studied the asymmetric impact of intervention on the exchange rate, it is confirmed that sale and purchase intervention can either destabilize or stabilize foreign exchange market depending on exchange rate depreciation or appreciation.

2.3.3 Central bank intervention in the Indian context:

There are few studies, which analyze the issues related to the effectiveness of central bank intervention in Indian context. Pattnaik and Sahoo (2003) attempt to measure the impact of RBI intervention on Rupee/USD exchange rate using Two Stage Least Square (TSLS) regression method. The empirical findings suggest that the RBI intervention by the net purchases of US dollar lead to appreciation of rupee against the dollar. This finding is contradictory to the theoretical expectation that the net purchase should lead to depreciation of the domestic currency. Thus, the study concludes that the RBI intervention is not effective in the influencing exchange rate level. However, intervention is found to be significant in reducing the exchange rate volatility. This indicates that RBI intervention is viewed as an effective instrument to mitigate exchange rate volatility in the foreign exchange market. The study also found that higher exchange rate volatility leads to aggressive intervention by RBI.

Unnikrishnan and Mohan (2003) analyze the effectiveness of RBI interventions on Rupee/USD exchange rate level and volatility for the period January 1996 to March 2002. Using GARCH, this study finds that RBI intervention is not effective in influencing Rupee/USD exchange rate level. However, empirical results gave an implication that the RBI follows leaning against the wind policy in the foreign exchange rate market as the net purchases of US dollar lead to depreciation of the rupee, though it is not statistically significant. In the context of volatility, intervention through net purchases of US dollar is significantly reducing exchange rate volatility. This means that intervention is effective in mitigating exchange rate volatility. Overall, this study confirms that RBI intervention is effective to reduce the volatility of exchange rate but

the study did not provide any evidence for whether it is a policy against appreciation or depreciation of rupee.

Behera et al. (2006) examine the impact of RBI intervention on the Rupee/USD exchange rate for the period June 1995 to December 2005. Using GARCH Method, the study finds that RBI intervention by net purchases of US dollar leads to rupee appreciation against the US dollar. This indicates that RBI intervention fails to curtain the ongoing appreciation trend and hence central bank intervention is not effective in determining the level of exchange rate. However, the net purchases of US dollar lead to fall in exchange rate volatility in the foreign exchange market. Therefore, authors confirm that RBI succeeds in mitigating the exchange rate volatility as stated in its objective of RBI intervention policy. Further, this study also shows that interest rate differential between India and US, reduces exchange rate volatility; and higher net foreign institutional investment inflows are associated with higher exchange rate volatility.

Inoue (2012) investigates a causal relationship between intervention and exchange rate volatility, using univariate EGARCH (Exponential GARCH) for period from December 1997 to December 2011. This study finds that there is causality from exchange rate volatility to intervention but not vice-versa in either spot or forward markets. This study concludes that RBI intervenes in the foreign exchange market in response to exchange rate volatility and similarly, the absence of causality from intervention to exchange rate. This study suggests that RBI intervention is not an effective instrument to mitigate the exchange rate. Further, the author attributes the low frequency data and low volume of

intervention to market turnover for the absence of causality from intervention to exchange rate volatility.

Goyal and Arora (2012) analyze the effectiveness of RBI intervention on Rupee/USD exchange rate using EGARCH model with both daily and monthly for the period November 2002 to December 2008. The study finds that RBI intervention leads to appreciation of exchange rate and increases in volatility after taking into account the effect of policy variables on the level despite RBI aimed to reduce exchange rate volatility. Most importantly, they found that communication variables are associated with reduction in exchange rate volatility. Further, EURO/USD affects the Rupee/USD movements. Over all, this study suggests that RBI intervention affects both the exchange rate level and volatility against stated objective of RBI intervention.

Unlike other studies, Kohli (2003) examine how exchange rate affects RBI intervention in the foreign exchange market during the period March 1993 to February 2001 using Two Stage Least Square method (TSLS). The findings suggest that RBI intervene in response to contemporaneous changes in exchange rate. Therefore, author argues that RBI follows leaning against the wind policy. Further, intervention is found to be associated with the deviation of exchange rate from equilibrium exchange rate i.e., PPP based exchange rate. Therefore, author argues that RBI intervention is consistent with a real exchange rate targeting, and a nominal exchange rate adjusted to compensate for increased inflation relative to that of its trading partners.

Sahadevan (2002) examines whether RBI intervention influences future monetary policy stance through verifying the signaling channel, for the period June 1995- May 2001.

Applying OLS and Granger causality test, the study finds that RBI intervention is not effective in stabilizing the exchange rate level and concludes that intervention is inadequate to bring the exchange rate to a desired direction. The results also provide support for leaning against the wind policy. Further, the study also finds that the RBI sterilizes its impact of reserve accumulation on monetary base by 20%. Hence, it concludes that there is a weak signal to support for intervention and future monetary policy stance. In addition, the causality test result indicates that RBI intervention does not have any causal relationship with monetary variables and exchange rate. Similarly, intervention causes changes in the level of foreign currency reserves.

Baig et al. (2003) make an attempt to estimate the impact of RBI intervention on the exchange rate for the period January 1993 - March 2002. The results suggest that RBI adopts leaning against the wind policy of intervention to prevent appreciation of the rupee. However, during the financial crisis such as South East Asia Crisis 1997 and Russian Financial Crisis, RBI prevents rupee depreciation by selling foreign exchange reserves. Further, the study concludes that RBI intervene to curb excessive volatility in foreign exchange market for maintaining trade competitiveness and accumulate foreign exchange reserves.

2.4 RESEARCH GAP

The literature shows that there are many studies that analyze the effectiveness of the RBI intervention in the foreign exchange market. The studies such as Unnikrishnan and Mahan, (2003), Beraha et al., (2006) and Sahoo and Pattnaik, (2003) empirically examined the effectiveness of the RBI intervention on the Rupee/USD exchange rate

level and volatility. However, these studies did not address the issues related to asymmetric effect of intervention on exchange rate. For instance, these studies measure intervention as the net purchases (purchases minus sales) of US dollar by RBI. However, it is found from the literature that there can be asymmetric effects related to purchases and sales on exchange rate level and volatility (see, Frenkel et al, 2004; Guimaraiesa and Karacadag, 2004; Lahura and Vega, 2013; and Domac and Mendoza, 2004). These asymmetric effects cannot be observed if intervention is measured by the net purchases alone. Hence, we can argue that the available studies in the Indian context did not try to address the asymmetric effect of RBI intervention on exchange rate level and volatility, by separating the effects of sales and purchases. Hence the present thesis addresses this research gap in the literature.

Relevance of asymmetric intervention in the Indian context:

In the Indian context, there is a possibility of asymmetric impact of intervention in the adjustment process of Rupee/USD exchange rate and in the curbing of the exchange rate volatility. Ramachandran and Srinivasan (2007) provide the evidence of asymmetric intervention by the RBI by arguing that RBI intervenes in the foreign exchange market when the rupee appreciates but not when the rupee depreciates. Further, this argument is supported by Prabheesh et al. (2009) that the RBI follows undervalued exchange rate polies against the US dollar to maintain the export competitiveness. Similarly, RBI (1993-94) argued that RBI intervened to prevent erosion of incentives that is available to exporters. This implies that the RBI pursues the intervention to slow down or moderate the rupee appreciation in the foreign exchange market.

These studies provide the indications that RBI can adopt asymmetric intervention policies, i.e., RBI follows stronger leaning against the wind policy during periods of appreciation than during depreciation, to protect the export competitiveness. Thus, this study examines the asymmetric effect of intervention on the exchange rate level and volatility.

2.5 OBJECTIVES OF THE STUDY

The two main research questions of this study are as follows:

- To analyze the effectiveness of RBI intervention on exchange rate level and volatility.
- To verify the relevance of asymmetric intervention.

Table No: 1.1 Empirical Studies and Variables

S.No	Author	Methodology	Variables
1.	Dominguez(1998)	Implied volatility and GARCH(1,1)	Implied volatility, intervention(secret and reported, interest rate differentials, day of week and holiday dummies, exchange rate policy news,
2	Bonser-Neal and Tanner (1996)	OLS, Implied volatilities of currency option prices	Implied volatility, intervention, reported and perceived intervention dummy, Macroeconomic announcements , Macroeconomic surprise, Monday dummy, stock exchange rate volatility
3	N.Brissimis and P. Chionis (2004)	GARCH	Exchange rate return, Intervention dummy, Monday dummy, interest rate differential
4	M.Bein et al.(2003)	Morkev Switching model	Unilateral intervention and coordinated intervention
5	J.Nagayasu (2004)	GARCH	Exchange rate return ,Intervention, interest rate differentials.
6	Aguilar and Nydahl (2000)	GARCH and Implied volatility	Intervention, interest rate differential, Speech, Spillover effect
7	Disyatat and Galati (2007)	Instrumental Variable Method	Change in spot rate, Intervention, risk reversal, implied volatility
8	Gilati et al. (2005)	Instrumental Variable Method	Changes in exchange rate(forward) changes, intervention, Monday effect, macroeconomic announcement, changes in interest rate
9	Futum and Hutchison (2003)	Event analysis	Intervention, change in the exchange rate, interest rate changes,
10	Fatum (2008)	Event analysis	Change in exchange rate, intervention, Co-movements of USD coordinated intervention
11	Chang and Taylor	GARCH	Exchange return, intervention and

	(1998)		macroeconomic announcements
12	Frenkel et al.(2004)	OLS with Implied volatility	Implied volatility, BUY and SELL dummy, intervention dummy, coordination dummy
13	Guimaraiesa and Karacadag (2004)	ACT-GARCH	Exchange rate return, sale and purchase interventions, spread, interest rate differentials
14	Michael Mckenzie (2002)	GARCH AND TGARCH	Exchange rate returns, Net purchase and sale intervention dummies, Small and larger intervention variable
15	Laura et al. (2013)	SVAR and Event analysis	Exchange rat return, purchases and sales intervention
16	Domac and Mendoza (2004)	EGARCH	Intervention, sale and purchase intervention , Signal dummy (signal of exchange rate policy, ON (intervention impact on money market,) BRADY (Brady bond yields)
17	Carman Broto (2012)	GARCH	Exchange rate return, intervention, purchases and sales intervention, size and first intervention.
18	Pattnaik and Sahoo (2003)	OLS	Exchange rate return, intervention, exchange rate deviation, interest rate differentials
19	Behera et al.(2006)	GARCH	Exchange rate return, Intervention (net purchase of USD), FII, interest rate differentials.
20	UnniKrishnan and Mohan (2003)	GARCH	Exchange rate return, intervention, open market operation, NEER and REER
21	Inoue (2012)	EGARCH	Spot and forward exchange rate, net purchase of dollar intervention.
22	Goyal and Arora (2012)	EGARCH	Exchange rate return, intervention dummy, interest rate differentials, communication

			variable (News, speech), EURO/USD
23	Kohli (2003)	TSLS method	Change in nominal exchanger rate, intervention (net purchase of USD), PPP based exchange rate, 1993 march base exchange rate
24	Sahadeven (2002)	OLS and Granger causality	Exchange rate, Intervention, money supply, central bank's net credit to government
25	Baig et al.(2003)	OLS	Intervention, exchange rate differentials , interest rate differential
26	Simwaka and Mkandawire (2012)	GARCH	Exchange rate return, intervention (net sale of USD), inflation differentials, exchange rate Premium, monthly seasonal dummies

CHAPTER 3

EMPIRICAL ANALYSIS

3.1 INTRODUCTION

In this chapter, we empirically analyze the effectiveness of central bank intervention on exchange rate and its volatility in the Indian context. This chapter is organized as follows: section 3.2 deals with the specification of empirical model and section 3.2 presents data source. Sections 3.3 and 3.4 discuss about econometric methodology and empirical results. And section 3.5 presents conclusion.

3.2 **EMPIRICAL MODEL**

In this chapter, we estimate two models to assess the impact of RBI intervention on the Rupee/USD exchange rate level and volatility. The first model analyzes the impact of RBI intervention on the exchange rate and its volatility by measuring intervention as net purchases of US dollar by the RBI. However, in the second model, we include both purchases and sales of US dollar by the RBI, as a proxy of intervention to examine the asymmetric impact of intervention.

Model I

Here we estimate baseline model to analyze the impact of RBI intervention on the Rupee/USD exchange rate level and volatility. We specify the following exchange rate level and volatility equations based on GARCH specification:

Level equation:

$$r_t = \beta_0 + \beta_1 np_t + \beta_2 ir_t + \beta_3 ird_t + \beta_4 fii_t + \beta_5 dum_t + \varepsilon_t \quad (3.1)$$

Volatility equation:

$$h_t = \alpha + \alpha_1 np_t \quad (3.2)$$

where *r* denotes the change in the exchange rate (exchange rate returns) and *np* indicates net purchases of US dollar by the RBI. Similarly, *ir* and *fii* represents interest rate and net foreign institutional investment inflows, respectively. Likewise *dum*, *t and* ε denote monthly seasonal dummies, time and error terms, respectively. Similarly, h_t stands for exchange rate volatility and $\beta_1, \beta_2, \beta_3 \beta_4 \; and \; \beta_5$ are the parameters to be estimated and β_0 is intercept. The measurement of the variables and the expected theoretical relationship between the exchange rate and its' determinants are discussed below.

Exchange rate returns (r_t)

This is dependent variable, i.e., the change in Rupee/ Dollar (Rupee/USD) exchange rate. The variable is measured by the first difference of the logarithmic exchange rate[6]. An increase in exchange rate returns indicates depreciation and a decrease indicates appreciation of rupee against the US dollar.

[6] Since we estimate this equation using GARCH method, all variables in the equation must be stationary. Hence most of the studies take first difference of the logarithmic exchange rate because exchange rate is generally non-stationary in levels.

Exchange rate volatility *(h_t)*

This is the dependent variable in exchange rate volatility equation. This is the conditional variance which is derived from GARCH model.

Intervention (np_t)

This is the proxy for intervention by the central bank in foreign exchange market. This is defined as monthly net purchases of US dollar (purchases minus sales) by RBI in billion rupees. Theoretically, the intervention is said to be effective, when an increase in net purchases (+) prevents the appreciation of the domestic currency or leads to depreciation. Hence, a positive relationship is expected between *np* and *r* in the level equation. Similarly, the intervention though net purchases is expected to reduce the volatility in exchange rate. Hence, a negative relationship is expected between *np* and *h* in the volatility equation.

**Interest rate (*ir_t)*:

According to the uncovered interest rate parity theory, a change in interest rate in the domestic market compared to foreign market leads to a change in the market participants' expectations and hence leads to a change in exchange rate i.e., a higher (lower) interest rate leads to appreciation (depreciation) of domestic currency. Hence, we expect a negative relationship between interest rate and exchange returns. In the present context, the interest rate is proxied by call money rate.

Inflation rate differential (*ird_t*):

Another important variables in the exchange level equation is inflation rate differential. According to relative Purchasing Power Parity theory, the change in inflation rate compared to trading partner countries will lead to a change in exchange rate i.e., a higher inflation rate differential leads to depreciation of domestic currency and lower inflation rate differential leads to appreciation in the foreign exchange market. Therefore, we expect a positive relationship between inflation rate differential and exchange rate returns. Inflation rate differential is measured by taking the difference between inflation in India (WPI based) and inflation in US (CPI based).

Foreign institutional Investment (*fii_t*):

FII captures the impact of short term capital flows on exchange rate. Since foreign institutional investors (FIIs) are the major players in the Indian foreign market, the Indian rupee is vulnerable to these short term flows. That is, a higher net FII inflows leads to appreciation of exchange rate and a lower net FII inflows leads to depreciation of exchange rate in the foreign exchange market. Therefore, we expect a negative relationship between FII and exchange rate returns.

Monthly dummies (*dum*):

The study also includes eleven seasonal dummy variables so as to capture the seasonal effect of the variables in the model.

Model II

In the second model, our main focus is to analyze the asymmetric impact of RBI intervention on the Rupee/USDs exchange rate level and volatility. In order to address this issue, we include sales and purchases of US dollar by the RBI in equations 3.1 and 3.2 instead of *np*. The level and volatility equations are specified as:

Level equation

$$r_t = \gamma_0 + \gamma_1 p_t + \gamma_2 s_t + \gamma_3 ir_t + \gamma_4 ird_t + \gamma_5 fii_t + \gamma_6 dum_t + \varepsilon_t \quad (3.3)$$

Volatility equation

$$h_t = \alpha + \alpha_1 p_t + \alpha_2 s_t \quad (3.4)$$

Where p_t denotes purchases and s_t denotes sales of US dollar by the RBI.

Purchases and Sales (p_t &s_t):

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 that 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 the exchange rate volatility in foreign exchange market and hence a negative relationship is expected between h_t and s_t, and h_t and p_t.

3.3 DATA AND DATA SOURCE

We use monthly data from July 1995 to July 2013 to estimate the equations from 3.1 to 3.4. 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 such as net purchases, purchases and sales of US dollar and net FII inflows are measured in the Rupee billion.

3.4 ECONOMETRIC METHODOLOGY

The equations from 3.1 to 3.4 are estimated by GARCH methodology. Prior to employ this technique, we need to ensure that all variables in the GARCH specification are in the same order. Therefore, we follow 2 test procedures: (1) Test for unit root to ensure that the variables in the model are stationary (2) estimate the above equations by GARCH method. We briefly discuss these methods below.

3.4.1 Unit root test or test of stationarity

Generally, a time series is said to be stationary, when its mean, variance and covariance are constant over the time. Time series which do not have this property is regarded as non-stationary or a random walk process. Practically, most of the macroeconomic and financial data are non–stationary because of their sensitivity to different shocks in the economy. This non-stationary data violates the desirable statistical properties of the estimators and gives misleading inferences. Thus, it is important to test the stationarity properties of time series before attempting any times series econometric exercise. The test generally follows a simple first order autoregressive process

$$Y_t = \mu_0 + \mu_{it} + \alpha Y_{t-1} + \varepsilon t \quad (3.5)$$

where (Y_t) is the stochastic process, and μ_0, $\mu_1$and α_1 are parameter and ε_t is a random disturbance term with white noise properties. μ_0 is called drift or constant or intercept. The nature of the time series described by the equation (3.5) depends on the parameter values. If $\mu_1<1$, $\phi\alpha\phi \prec 1$ then Y_t follows a deterministic trend. The presence of autoregressive component, α_{Yt-1}, represents there may be short-run deviations, but the series will return to trend eventually. Such kind of series is called as a trend stationary (TS) process, as the residuals from the regression of Y_t on a constant and a trend will be stationary. If $\mu_0=0$, $\mu_1=0$ and $\alpha_1 = 1$, the series follows a simple random walk, a unit root process. If $\mu_0\neq0$, $\mu_1=0$ and $\alpha_1 = 1$, the series follows a random walk with drift. Any stochastic process is said to be a difference stationary (DS) process, which become stationary after differencing once. Similarly, any time series is said to be TS process which becomes stationary after de-trending.

For this present study, we use widely used two unit root tests such as Augmented Dickey Fuller (ADF, 1981) and Phillip Perron (PP, 1988)) unit root tests. For ADF unit root test we estimate following equation

$$Y_t = \mu_0 + \sum \alpha_i Y_{t-1} + \varepsilon_t \quad (3.6)$$

This can be rewrite as

$$\Delta Y_t = \mu_0 + \delta\, Y_{t-1} \sum_{i-2}^{p} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \quad (3.7)$$

where, $\delta = -(1 \sum_{i=1}^{p} \alpha_i)$ and $\beta_i = p \sum_{j=1}^{p} \alpha_j$

where $\Delta Y_t = Y_t - Y_{t-1}$. The null hypothesis is that the Y_t process has a unit root, i.e., H_0: $\delta=\alpha_1=0$ since $-1\leq\alpha\leq1$, it follows that $-2\leq\delta\leq0$ There are different forms of ADF tests by including trend terms in equations (3.6) and (3.7) and also excluding drift (intercept or constant) term, μ_0, from these equations.

To test the significance of δ (3.5) and (3.7), the Student's t-statistics critical values cannot be used. Initially, Dickey-Fuller and later MacKinnon have developed the appropriate test statistic known as t-statistic and its critical values using Monte Carlo simulations. The critical values of t-statistic made available under alternative assumptions of drift, trend, sample size and level of significance. They are abbreviated as *l* (no drift and no trend), l_μ(only drift) and l_t (with both drift and trend). Dickey-Fuller values, known as ϕ_1,ϕ_2 ϕ_3, for pair-wise joint tests of significance for μ_0 and μ_1. Thus, the null hypothesis that $\delta = 0$ can be rejected if the computed t-value for the coefficient δ is greater than the critical t-value in absolute magnitude. It has been shown that the same DF test critical values are valid for the ADF test as well.

In the case of Philips and Perron unit root test, this test is similar to ADF test. However. it differs ADF from PP in dealing with serial correlation and heteroscedasticity in the errors. ADF test uses a parametric autoregression to approximate the ARMA structure of the errors in the test regression whereas PP test uses non-parametric modified Dickey Fuller statistics to correct any serial correlation in errors.

3.4.2 ARCH AND GARCH Model

Financial time series such as stock prices, exchange rate 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:

$$y_t = \mu + \varepsilon_t \tag{3.8}$$

$$h_t = \omega + \sum_{t-i}^{p} \alpha_i \, \varepsilon_{t-i}^2 \tag{3.9}$$

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

Equation (3.8) 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 (3.9) 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)

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

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 \, \alpha_i + \sum_{i=1}^{q} \beta_i \, h_{t-i} \qquad (3.10)$$

In order to ensure that h_t>0, parameters in Equation (3.10) 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 value 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.

After estimation of GARCH model, it is customary to check the volatility structure by analyzing the Ljung-box Q-statistics of standardized residual and squared standardized squared residuals so as to confirm whether there is any remaining autocorrelation or not in the squared residual and residual term up to lag *k*.

GARCH specification of central bank intervention

We use GARCH (1,1) in the context of RBI intervention and exchange rate nexus, in this study, in order to observe the impact of intervention on the exchange rate level and volatility. We specify following GARCH equation for intervention.

$$r_t = \beta_0 + \beta_1 np_t + \beta_2 ir_t + \beta_3 ird_t + \beta_4 fii_t + \beta_5 dum + \varepsilon_t \quad (3.11)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta h_{t-1} + \delta np_t \quad (3.12)$$

In conditional mean equation (3.11), conditional mean is a function of net purchases of US dollar and its other determinants. In the conditional volatility equation (3.12), conditional volatility is a function of lagged squared residuals and lagged squared conditional variance in additional intervention.

We specify the following GARCH model II to analyze asymmetric effect of intervention on the exchange rate level and volatility:

$$r_t = \gamma_0 + \gamma_1 p_t + \gamma_2 s_t + \gamma_3 ir_t + \gamma_4 ird_t + \gamma_5 fii_t + \gamma_6 dum + \varepsilon_t \quad (3.13)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta h_{t-1} + \delta_1 p_t + \delta_2 s_t \quad (3.14)$$

3.5 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.

3.5.1 Descriptive Statistics

Descriptive statistics the variables are presented in Table 3.1. This table shows that Rupee/USD exchange rate returns average (mean) value of 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

Table 3.1: Descriptive Statistics

Variable	Rt	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

also interesting to see that the mean value of purchases is higher than the mean value of sales. 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 is negatively 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.

Unit Root Results

Table 3.2 shows that both ADF and PP test statistics reject the null hypothesis of non-stationary in the case of all variables, implies that all variables are stationary at level, i.e., I (0). Hence these variables can be used for the estimation using GARCH method.

Table 3.2: Unit Root Test Results: At level

Variable	Augmented Dickey Fuller Test		Phillip Perron Test	
	Test statistic	p-value	Test statistic	p-value
r_t	-11.818	0.000	-11.726	0.000
np_t	-4.520	0.000	-8.560	0.000
p_t	-3.024	0.002	-6.079	0.000
s_t	-3.460	0.000	-6.252	0.000
ir_t	-1.810	0.066	-2.375	0.017
ird_t	-0.496	0.500	-2.110	0.033
fii_t	-4.411	0.000	-8.405	0.000

Note: r_t=exchanger rate return, np_t=Net purchases of US dollar, p_t =Purchases of US dollar, s_t =sales of US dollar, ir_t = Interest rate, ird_t =inflation rate differential, fii_t =Net Foreign institutional Investment inflows.

3.5.2 GARCH Results

We estimate the model I using GARCH (1,1) to analyze the effectiveness of intervention on the exchange rate level and volatility, and the results are reported in Table 3.[7]

[7] We applied the student t-distribution with BBBH algorithms which are more stable and robust and give better results than Marquardt to obtain coefficient of model (Goyal and Arora, 2012). To avoid the dummy variable trap in the estimation, we didn't include constant in the exchange rate level equation (Berument et al.,2001).

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 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.

Second part of the Table 3.3, 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 stationarnarity of variance and the presence of

Table 3.3: GARCH Results (Model 1)

Conditional Mean		
Variables	Coefficients	t-statistic
np_t	-4.20E-06	-0.740
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	-1.920***
ma_ dum	0.015135	6.12*
jun_ dum	0.004047	1.11
jul_ dum	0.003496	0.90
aug_ dum	0.00706	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 0.0001	4.05*
GARCH(β)	0.919464	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*

short memory. The evidence of stationarity of variance suggests that exchange rate volatility reaches its long term average value as the forecast prediction origins increases.

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 series of exchange rate return is shown in Figure.3.1

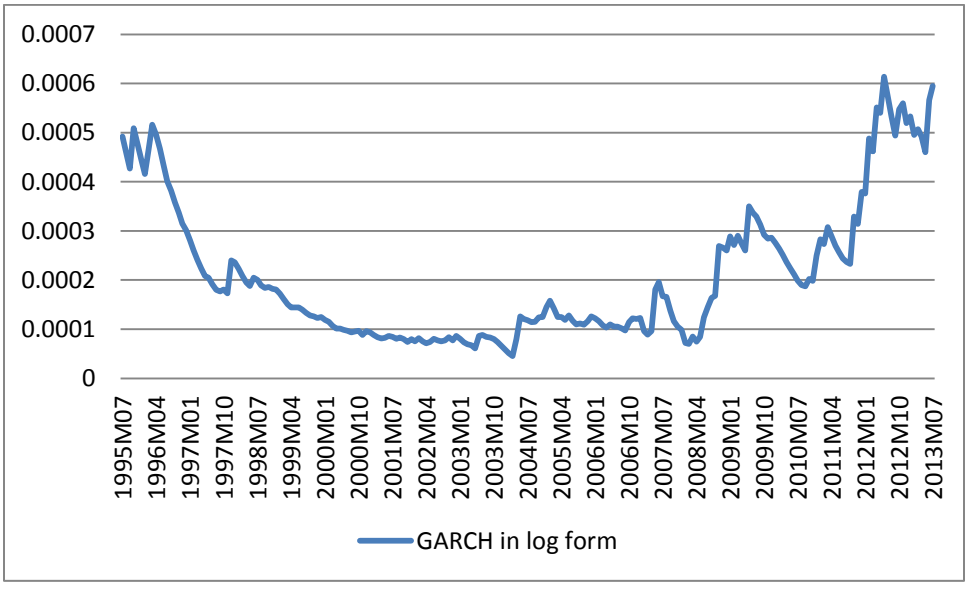

Figure: 3.1 Conditional Variance (Model 1)

Similarly, we estimate the model II using GARCH method to analyze the asymmetric impact of intervention on exchange rate level and volatility and the results are reported in Table 3.4. 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. 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.

The findings related to other explanatory variables in the equation such as idf_t,ir_t,and fii_t are similar to Table 3.3, hence, we do not repeat the explanation in this section.

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 the exchange rate volatility, whereas intervention by sales increases the exchange rate volatility. This supports the evidence of asymmetric impact of intervention on the exchange rate volatility. The significant increase in volatility due to sales may be attributed to the lack of credibility of

Table 3.4 GARCH Results (Model 2)

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	0.0026	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)		

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*

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. The model diagnostics do not provide any evidence of serial correlation and ARCH effect on residuals. Log of conditional variance series of exchange rate returns is shown in Figure 3.2.

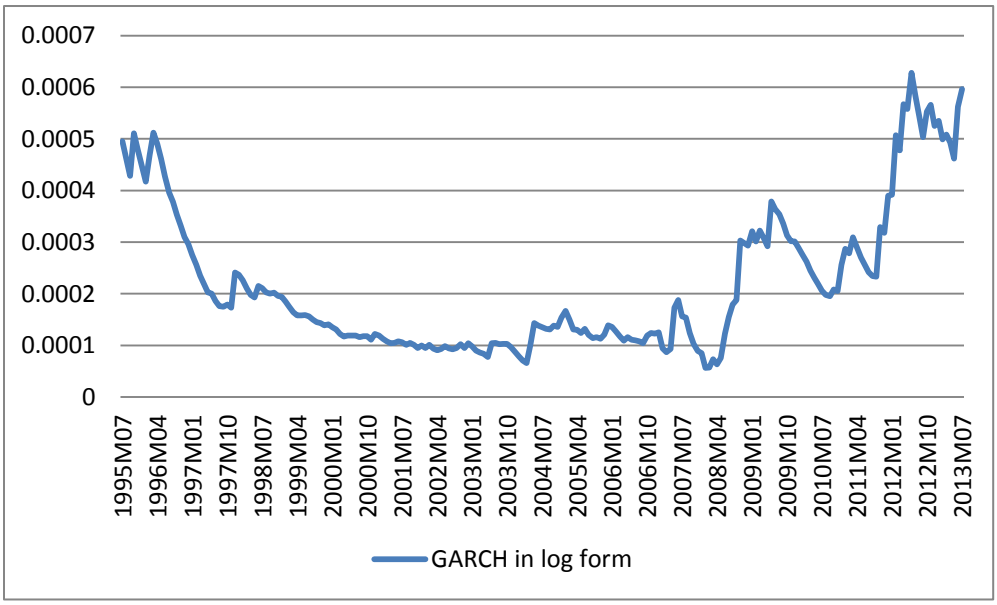

Figure: 3.2 Conditional Variance (Model 2)

3.6 CONCLUSION

This chapter empirically analyzes the impact of RBI intervention on Rupee/USD exchange rate level and volatility for the period July 1995- July 2013. We estimate two models i.e., first model analyzes the effect of intervention on the exchange rate level and volatility by measuring intervention as net purchases of US dollar by the RBI. In second model, we include both purchases and sales of US dollar, instead of net purchase, to analyze the effect of asymmetric intervention on exchange rate level and volatility. We estimated both models by employing GARCH methodology. The results based on model I shows that RBI intervention is not effective in influencing the level of Rupee/USD exchange rate, implying that the exchange rate is market determined. However, in the case of exchange rate volatility, we found that the RBI intervention is effective in reducing the volatility.

The empirical findings of the second model provide some evidence of 'leaning against the wind policy' during the period of appreciation, and 'leaning with the wind policy' during the period of depreciation of rupee against the US dollar. Further, the empirical findings show that intervention by purchases significantly reduces volatility whereas intervention by sales significantly increases volatility of exchange rate. This indicates that RBI effectively reduces exchange rate volatility during the period of exchange rate appreciation of rupee against the US dollar in the foreign exchange market. On the other hand, intervention by sales of US dollar, during the period of depreciation, does not lead to any reduction in volatility of exchange rather it increases volatility.

CHAPTER 4

SUMMARY AND CONCLUSIONS

In the recent years, most of the developing countries experienced high volatility in their exchange rates due to high financial integration. To mitigate the adverse effect of high exchange rate volatility on economy, most of the central banks in the developing countries started intervening in the foreign exchange market to target a desired level of exchange rate or to reduce the volatility in exchange rate. The central bank of India, RBI, is also frequently intervening in the foreign exchange market and thereby the foreign exchange reserves with the RBI increased dramatically over the last ten years. Therefore, this thesis addresses the effectiveness of RBI intervention in the foreign exchange market.

The thesis is organized in four chapters. In introduction i.e., the first chapter, discussed the definition, channels of influence and trends in intervention in global and Indian context. Trends in intervention show that there is a frequent intervention by the central banks of developing countries. More specifically, the RBI intervention is very frequent during 1995-2013. It is also found that the RBI is the net purchaser of USD during the same period. Chapter 2 provides a comprehensive and critical survey of theoretical and empirical literature on issues related to the intervention. After reviewing the literature, the study came up with two objectives that are not addressed in the literature in the Indian context.

- To analyze the effectiveness of RBI intervention on exchange rate level and volatility.
- To verify the relevance of asymmetric intervention.

Chapter 4 of the thesis empirically estimated two models to analyze the above two objectives using monthly data from July 1995 to July 2013. First model analyzes the effect of intervention on the exchange rate level and volatility by measuring intervention as net purchases of US dollar by the RBI. In second model, we include both purchases and sales of US dollar, instead of net purchase, to analyze the effect of asymmetric intervention on exchange rate level and volatility. Both models are estimated by employing GARCH methodology. The results based on model I show that RBI intervention is not effective in influencing the level of Rupee/USD exchange rate. However, in the case of exchange rate volatility, the study found that the RBI intervention is effective in reducing the volatility.

The empirical findings of the second model provide some evidence of 'leaning against the wind policy' during the period of appreciation, and 'leaning with the wind policy' during the period of depreciation of rupee against the US dollar. Further, the empirical findings show that intervention by purchases significantly reduces volatility whereas intervention by sales significantly increases volatility of exchange rate. This indicates that RBI effectively reduces exchange rate volatility during the period of exchange rate appreciation of rupee against the US dollar in the foreign exchange market whereas intervention by sales of US dollar, during the period of depreciation, does not lead to any reduction in volatility of exchange rather it increases volatility.

This finding has some policy implications. *First*, if RBI wishes to target the level of exchange rate, then it has to intervene with huge amount of purchases and sales relative to market turnover. It implies that the existing size of intervention is not sufficient to target the level of exchange rate.

S*econd*, since the study found that the intervention by sales increase risk in the market and thus the RBI may have to come-up with certain policies which enhance its credibility while intervening through sales.

This study has two limitations. *First*, this study used monthly data to analyze all the dynamics of intervention due to the lack of availability of daily data. However, the daily data will be more appropriate to capture the intervention dynamics. *Second*, the asymmetric impact of intervention can be further studied with the help of most recently developed asymmetric methods such as E-GARCH and T-GARCH etc. This research issue can be further studied.

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