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Abstract

We study, with daily and monthly data sets, the impact of conventional monetary policy measures such as interest rates, intervention and other quantitative measures, and of Central Bank communication on exchange rate volatility. Since India has a managed float, we also test if the measures affect the level of the exchange rate. Using dummy variables in the best of an estimated family of GARCH models, we find forex market intervention to be the most effective of all the CB instruments evaluated for the period of analysis. We also find that CB communication has a large potential but was not effectively used.

Keywords:

exchange rate volatility, monetary policy, intervention, communication, GARCH

JEL Code:

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1. Introduction

Research on monetary policy has seen exponential growth, but the rich and challenging experiences in emerging markets are still under-explored. In this paper we estimate the best model in the family of autoregressive conditional heterosckedasticity (ARCH) and generalized ARCH (GARCH) models of exchange rate volatility, for the period following maturing of Indian policy, money and FX markets. Then we insert policy dummies to study the impact on exchange rate volatility of conventional monetary policy measures such as interest rates, intervention and other quantitative measures, and of Central Bank (Reserve Bank of India, RBI) communication[1]. Since India has a managed float, it is worthwhile to test if the measures also affect the level of the exchange rate.

This is a rich period to analyze the effectiveness of various instruments since the movement towards freer markets implies a large range of policy instruments continue to be used. An assessment of their relative impact is a contribution towards understanding transition and towards determining the way forward. In an emerging markets facing potential market instability from volatile capital flows, alternative instruments can give valuable degrees of freedom to the Central Bank.

In the past decade, India has seen rapid development in markets, institutions and in instruments of monetary policy. A liquidity adjustment facility (LAF) has been introduced and the overnight inter-bank loan rate (the call money rate) has largely been kept in a band between two policy rates through injections and absorptions of liquidity (Ghosh and Bhattacharya, 2009).

[1] Fišer and Horváth (2010) use policy dummies in an equation for exchange rate volatility, and Ghosh and Bhattacharya (2009) do so in a GARCH model of the money market.

In India, monetary policy follows a multiple indicator approach, thus giving weight to both inflation and growth. Though RBI is not formally independent, series of measures have been taken to grant greater independence after the liberalizing reforms of the early nineties[2]. A populous low per capita income democracy, where inflation is a politically sensitive issue, requires a rapid response by monetary authorities to contain inflationary expectations. At the same time, developmental issues cannot be ignored.

The stated aim of Indian exchange rate policy is to reduce volatility, while the level is market determined around fundamentals. The period under analysis has seen movement away from a fixed exchange rate, relaxation of controls on the current account of the balance of payments, and partial capital account convertibility. There are no restrictions on equity flows. Surges in inflows have created problems for monetary management. Despite a current account deficit, reserves crossed $300 billion mark in 2008. Development of foreign exchange markets has been rapid. The average daily turnover in Indian FX markets, which was about US $3 billion in 1998-99, grew to US $48 billion in 2007-08, the fastest rate of growth among world markets BIS (2007). Growth in derivatives especially was strong, increasing to more than double spot transactions (Goyal, 2010).

The RBI is not at the point of the impossible trinity, where monetary policy becomes ineffective, since the exchange rate is not fixed, and the capital account is not fully open. But it is a challenge to address the needs of the domestic cycle while managing external shocks. An important question is the impact of policy rates on the exchange rates. If this impact is low then rate change can be targeted to the domestic cycle. Alternative policy instruments are required also if segmented domestic financial markets make it difficult to close interest differentials or differences in domestic and international policy cycles require positive differentials. The latter became obvious in the exit from crisis policies emerging markets faced inflation while mature markets still battled deflation. As larger FX market turnover and rapid market deepening makes standard intervention less effective, communication could offer an additional instrument to policy.

Evidence on Central Bank (CB) communication, largely for developed countries, is surveyed in Blinder et. al. (2008). They argue that communication makes monetary policy more

[2] For example, there is no longer automatic financing of the fiscal deficit.

effective either by creating news, or by reducing noise when the economic environment or the policy rule is not stationary so there is learning[3]. In such an environment expectations cannot be rational. In addition there can be asymmetric information between the public and the CB. Since uncertainties are pervasive in emerging markets, communication should have a larger effect there.

According to Posen (2002) CB transparency can work in a number of ways depending upon how effectively CB is able to maintain credibility and how public expectations are formed. He discusses six basic positions on CB transparency/communication: Reassurance view, detailed view, irrelevance view, contingent view, annoyance view and diverting view. Ehrmann and Fratzscher (2005) conclude that not only does CB communication matter but its timing also plays a crucial role. Communication becomes intense before any monetary policy meeting to prepare the market for the forthcoming decisions. Fratzscher (2005) analyzed the effect of oral as well as actual intervention on exchange rate levels using time series and event study analysis for US. He found oral interventions to be highly successful in moving exchange rate in the desired direction as compared to actual interventions. Goyal *et. al.* (2009) demonstrate this theoretically, and present some evidence for India in a study of strategic interaction between monetary policy and FX markets. Egert (2007) studies the effect of forex interventions along with the effect of interest rate news and verbal communication on exchange rate level and volatility for emerging markets in European union using event study analysis. He found that appropriate CB communication enhances the effect of actual intervention and interest rate news since each measure amplifies the effect of the others. Fatum (2009) analyses the impact of official Japanese intervention on JAP/USD exchange rate. He found portfolio balance channel more effective compared to signaling channel. Fišer and Horváth (2010) show that Czech National Bank communication tends to decrease exchange rate volatility using a GARCH framework. A lot of work has been done to analyse the effect of CB communication on financial markets. Literature on the effect CB communication on exchange rates, to which our paper contributes, is still in a nascent stage, especially for emerging markets.

[3] Empirical literature studying CB communication has grown rapidly in the last decade, as conventional wisdom in CB circles changed from saying as little as possible to the importance and the art of managing market expectations. Communication has become an important part of monetary policy.

The basic question we address is 'What is the impact of various types of intervention (verbal and actual) and monetary policy measures on Indian exchange rate volatility and level?' Policy measures are classified as follows:

-Interest rates: Reverse repo rate, repo rate

-Quantitative variables: Intervention, liquidity absorption or injection, cash reserves

-Communication variables: Review, speeches

-Controls: News, interest rate differential, US Federal Open Market Committee Meetings

Since our aim is to study the effect of all these variables on the exchange rate, time series modeling is most appropriate. In event study analysis one can only ascertain the impact of 2-3 variables at a time and the result is highly influenced by subjective judgment.

We find foreign exchange (FX) market intervention to be one of the most effective of the CB instruments evaluated for the period of analysis. It decreases volatility at both daily and monthly frequencies. Announcements on reserve requirements decrease volatility in the short period but both announced and actual changes raise it over time. Higher charges for liquidity injection increase monthly volatility, whereas higher payments for liquidity absorption reduce volatility at both frequencies. Interestingly more news decreases daily volatility. Interest rate differential increases volatility. There is also evidence of US monetary policy announcements impacting domestic markets, increasing daily variance but decreasing it at the monthly level. Speeches decrease daily volatility, but review has the opposite effect at the monthly frequency.

Since the exchange rate is a managed float we also test if policy dummies affect the exchange rate itself, and find evidence of this. CB intervention effectively appreciates the exchange rate, as do speeches at the daily frequency although this may be capturing the effect of large inflows occurring during our data period. At a monthly level, review and higher interest rate differential depreciate the exchange rate. The latter's negative effect on expected future returns maybe discouraging inflows more than the higher current differential encourages them. US Federal Reserve announcements appreciate the daily level. The results imply that communication channels have potential but are not being used effectively.

The structure of the paper is as follows: section 2 discuses data and methodology followed by section 3 which analyses the empirical results. Section 4 concludes.

2. Data and Methodology

We use both daily and monthly data. The daily data set is from 1st November 2005 to 31st December 2008, giving a total of 1157 observations. The monthly data set is from January 2002 to December 2008, that is, a total of 84 observations. We have enough observations to carry out time series analysis both in the daily and in the monthly case. The monthly data period starts with the adoption of LAF[4], while the daily data period covers a time of large exchange rate volatility, when the LAF had reached greater maturity. The daily frequency is required since markets may take several days to absorb the news, while the monthly frequency picks up greater strategic interaction, feedback and simultaneity. Moreover, the RBI does not release high frequency intervention data, therefore the impact of published intervention data can only be examined at the monthly frequency. Data sources are given in Appendix A.

GARCH models for exchange rate returns at the monthly and daily frequency provide a measure of exchange rate volatility. A number of models were estimated by maximizing the log-likelihood through an iterative process[5]. The best were selected based on diagnostics such as AIC, SIC[6], F-tests, and the Q-test[7]. The models cannot be arbitrarily fitted. Autocorrelation has to be taken care of, along with the concerns for degrees of freedom. Both monthly and daily data have different characteristics and they bring out different aspects of the market.

The best fitting models selected are given below.

AR (3) GARCH (1,1) for daily data:

[4] Therefore observations prior to 2002 could not be used also due to non-availability of certain variables.

[5] Estimation was done in Eviews using both the Marquardt and the BHHH algorithms. The results with BHHH were
more stable and robust. E. Berndt, B. Hall, R. Hall, and J. Hausman developed BHHH. It uses only the first derivatives of the objective function during the iteration process. In most cases it gives better results compared to Marquardt.

[6] The lower are AIC and SIC the better the model, since the tests are based on the residual sum of squares.

[6] This checks the null hypothesis that there is no remaining residual autocorrelation, for a number of lags, against the alternative that at least one of the autocorrelations is nonzero. The null is rejected for large Q values.

$$\Delta lnex_t = c + \sum_{i=1}^{3} \phi_i \Delta lnex_{t-i} + \varepsilon_t \qquad \text{Mean equation}$$

$$\sigma_t^2 = \alpha + \beta\varepsilon_{t-1}^2 + \gamma\sigma_{t-1}^2 + \delta_i \sum_{i=1}^{n} CB_{it} + \lambda_1\, intdiff_t + \lambda_2 news_t \qquad \text{Variance equation}$$

AR (1) and GARCH (1, 1) for the monthly data:

$$\Delta \ln ex_t = c + \phi \Delta \ln ex_{t-1} + \varepsilon_t \qquad \text{Mean equation}$$

$$\sigma_t^2 = \alpha + \beta\varepsilon_{t-1}^2 + \gamma\sigma_{t-1}^2 + \delta_i \sum_{i=1}^{n} CB_{it} + \lambda_1\, intdiff_t \qquad \text{Variance equation}$$

Both these specifications make residuals and squared residuals white noise, implying unmodelled autocorrelation is not left in the data. Taking first differences eliminated the unit root in levels. The mean equation estimates the first difference of the log exchange rate (a measure of exchange rate returns). The constant term *c* gives the average rate of depreciation or appreciation. Daily data requires three lagged terms in mean equation whereas monthly equation requires only one. The GARCH model then specifies the conditional variance σ_t^2 of the error term ε_t. It includes a constant, lagged error variables (ARCH terms), lagged conditional variance (GARCH term), and a number of variables capturing central bank actions (CB_{it}). The interest differential ($intdiff_t$), a news variable ($dvnews_t$), and US CB announcements are controls variables constituting the environment in which the CB and markets act and react.

Since the Indian policy objective is to reduce exchange rate volatility, including all these monetary policy variables allows us to test their relative effectiveness. That is, do they reduce exchange rate volatility or further aggravate it? As CB intervention creates news, volatility can be expected to increase in tick-by-tick data. But over longer periods the CB may successfully reduce volatility. Especially if information is scarce more news can reduce volatility.

In mature markets, the exchange rate is expected to be a random walk around equilibrium levels. But in emerging markets with large reserve accumulation, the exchange rate regime is more properly a managed float. So, although affecting the exchange rate level is not a stated policy objective, it is worthwhile to check if the policy dummies affect the level of the exchange rate.

The policy dummy variables included in CB_{it} are:

$dvacrr_t$ - It is the dummy variable, which takes value 1 when any change in the cash reserve ratio (CRR), commercial bank reserves with the RBI, is announced by the RBI or is 0 otherwise.

$dvecrr_t$ –This dummy variable takes value 1 when CRR change effectively comes into force or is 0 otherwise.

$dvrep_t$- This dummy variable takes the value 1 when the repo rate is changed. It is 0 otherwise. The repo rate, the upper bound of the liquidity adjustment facility (LAF) corridor, is the rate at which RBI lends in the LAF.

$dvrev_t$-This dummy variable takes the value 1 when the reverse repo rate is changed or is 0 otherwise. The reverse repo rate is the rate at which the RBI absorbs liquidity in the LAF, thus constituting the lower bound for the LAF.

$dvreview_t$- It takes value 1 whenever RBI reviews policy and makes a policy announcement, and is 0 otherwise. Prior to 2005, RBI used to review once in 6 months, after that the frequency was increased to once in three months.

Weighted dummy variables:

$speeches_t$ - It is a categorical variable taking different values depending on which RBI top official has given a speech and when the comments on the economy or on policy were made. It takes the value 3 when the RBI governor gives a speech and 4 when this speech is given within a week before or after the meeting. It takes value 1 when any of the three deputy governors gives a speech and 2 when a speech is given within one week before or after the meeting.

$wtlafps_t$- It is purchase minus sale in repo/ reverse repo auctions in LAF, that is, net injection (+) minus net absorption (-) of liquidity by RBI. We use it as an instrument for daily intervention because intervention changes domestic liquidity, which requires to be sterilized. Especially in our data period, since inflows were high, and LAF absorption was extensively used to mop up liquidity. $wtlafps_t$ takes value 0 when intervention is 0, value –1 when it is between -39500 and 0, and value –2 when it is less than -39500. Similarly, for adjustment greater than 0 and less than 39500 it takes value 1 and greater than 39500 it takes value 2.

$wtintvnet_t$- Intervention, defined as purchase minus sale of USD, takes value 0 when intervention is 0. For intervention between -6812 and less than 0 it takes value –1. For intervention less than -6812 it takes value -2. Similarly, for intervention greater than 0 and less than 6812 it takes value 1 and greater than 6812 it takes value 2.

Cluster variables:

$Intrate_t$ -This cluster variable is a combination of repo and reverse repo changes. It takes value 0 when none of them change, 1 when either of the two changes and 2 when both change together.

$Comm_t$ –As the name suggests, it is a communication variable, which combines domestic communication variables. It is a combination of $review_t$ and $speeches_t$. If neither change it takes value 0, when either or both of them change it takes different values depending upon who made the speech and when (as described earlier).

$Quant_t$ - It combines quantitative variables $dvecrr_t$, $dvacrr_t$ with $wtlafps_t$ for daily regressions and with $wtintvnet_t$ for monthly regressions. If neither of the variables changes it takes value 0, if one of them changes it takes value corresponding to that variable. If two change together it simply adds up the values taken by those two variables. Similarly, when all of them change together ($dvecrr_t$ and $dvacrr_t$ are dummy variables but $wtlafps_t$ and $wtintvnet_t$ are weighted variables.)

Macroeconomic control variables:

$dvnews_t$ -The daily specification includes a macroeconomic news variable ($dvnews_t$). This was constructed as a dummy variable taking a value of unity on the days macroeconomic news on production or pricing is released on government and RBI websites.

$intdiff_t$ -The interest rate differential is defined as the difference between the Indian call money rate (*cmr*) and the US federal fund rate (*ffr*). This captures the fundamentals determining the short-term exchange rate based on uncovered interest parity under the asset approach to FX markets.

$dvfomc_t$-This stands for the US federal open market committee meeting which takes place 8 times a year. Whenever this meeting takes place this dummy variable takes the value 1, and is 0 otherwise.

Descriptive statistics (Table A1a and A1b in Appendix B) show the daily call money rate on an average exceeded the federal fund rate by about 2.5 percentage points and monthly call money rate by 3.21 percentage points. Since $wtlafps_t$ is negative, on an average liquidity was sucked out of the economy for the period, indicating sterilization associated with accumulation of foreign currency. The frequency of RBI meetings is less than half of that of federal open market committee meetings ($dvfomc_t$) and RBI communication through speeches almost matches that of macroeconomic news. Mean of announcement of CRR change is lower than the mean of the effective implementation date. This is because implementation is generally spread over a longer period of time, normally in 2-3 stages. In the period of analysis, the repo rate was changed more often compared to the reverse repo rate. The Jarque-Bera test based on the 2^{nd} and 3^{rd} moments is large, showing severe non-normality, as is to be expected in daily and monthly data.

The correlation coefficients (Table A2a and A2b) among the policy variables are not very large, but repo, reverse repo rate changes and announcements do tend to be clustered with the policy review meetings. The highest correlation of 0.4 between $wtlafps_t$ and $intdiff_t$ suggests that when interest differentials are large absorption is required to offset the impact of arbitraging inflows. Correlations are higher at the monthly frequency. Large correlations imply multicollinearity in the regressions[8]. So, as a further caution we run regressions with the dummy variables one by one, in clusters and all together, subjected to the control variables. We also use many weighted dummies.

3. Empirical Results and Analysis

Table 1 summarizes the policy instruments that are significant, and gives their signs. It also allows us to see how the monthly affect, which allows for policy feedback and simultaneity, differs from the short-run daily effect. The estimations are reported in Appendix C tables, with the equations estimated in each case given above the tables.

Multicollinearity issues from using many dummy variables are ruled out since results with all the dummies are largely consistent with regressions of the dummy clusters and of each dummy alone with controls. Regressions were repeated in each case for all variables together, dummy clusters, and each dummy alone with controls[9], if the controls were significant. The many regressions estimated all generally support the coefficients in Table 1 (the bracketed terms in Table 1 are the only case where they differ). Thus the results are robust.

Variables, which measure quantitative FX market intervention, such as $wtlafps_t$ and $wtintvnet_t$ have meaningful impact in all their relevant categories. Thus $wtlafps_t$ reduces daily variance and appreciates the daily exchange rate, while $wtintvnet_t$ reduces monthly variance and appreciates the monthly exchange rate. The sign of the cluster variable $quant_t$ is same as the FX market intervention variables, which dominate in a regression of the $quant_t$ variable with controls (Table A3 and A6).

Most studies of an earlier period find that RBI intervention decreases volatility (Edison et. al., 2007, Pattanaik and Sahoo, 2003, Goyal[10] et. al., 2009). Goyal et. al.(2009) find in addition, that daily FX market turnover increases with RBI intervention. In informal conversations, FX dealers often suggest that RBI intervention can increase FX market activity. Dealers with private information, who anticipate RBI action and its effect on the exchange rate, would use

[8] If two variables are perfectly correlated, variance becomes infinity. So significance is low even if R^2 is high, the results are dependent on the data set, and coefficients can have the wrong sign or size. Multicollinearity is a common problem when a large number of dummy variables are used. But many of our dummies are weighted variables. Moreover, highest VIF was only 1.4 suggesting very low multicollinearity in our data set.

[9] Regressions were also done without controls but were discarded since the policy variables would then be affected by the omitted variables bias.

[10] While the earlier two studies use OLS, this study uses GMM, controlling for simultaneity.

this to buy or sell, making money at the expense of less informed market participants. Any shock/new information to markets would increase expected returns and therefore volatility in high frequency data capturing actual trades. This is the creating news function of CB action. But studies show that in longer horizons the effect can be in either direction (Blinder et. al, 2008). In the long run no news remains unprocessed. In the net CB action enhanced scarce news and decreased the volatility of returns.

In the Goyal et. al.(2009) study, the CB's reported intervention does not affect exchange rate levels. But a broader measure of the CB's actions in the FX market, the change in reserves, depreciates the exchange rate. Our weighted dummy intervention variables are also, in a sense broader measures, since they give the same value to blocks of intervention. So their significant effect on levels is consistent with the earlier result. The Goyal et. al. study was able to control for turnover, since it used a simultaneous equation technique. So it found that reserve accumulation depreciated the exchange rate. The negative coefficients of the intervention dummies here maybe capturing the fact intervention was going on when high inflows were appreciating the exchange rate. High frequency data on foreign inflows is not available to serve as a control.

Quantitative intervention in the money market, through changes in the cash reserve requirement imposed on banks, has effects that are reversed over longer horizons. Although announced CRR ($dvacrr_t$) decreases daily variance (Table A3), $dvacrr_t$ and effective CRR ($dvecrr_t$) both increase monthly variance (Table A5). This interesting result possibly highlights limitations of blunt quantitative instruments. In the longer period markets may be able to get around restrictions, and overreact, or the bulk adjustments required may be obstructing smooth market adjustment. That $dvecrr_t$ does not effect daily variance while $dvacrr_t$ does suggest that since markets react to the announcement, the action itself is ineffective.

Among communication variables, $speeches_t$ (which can be measured only at the daily frequency) is persistently significant, appreciating the daily exchange rate and decreasing its variance. An interesting observation is that $speeches_t$ becomes insignificant if the control variable news is dropped. Therefore $speeches_t$ can be said to be playing an important role in interpreting and moderating the impact of news on the markets. This reflects the credibility of the RBI and the weight given to its pronouncements by public due to its strong balance sheet and reserves. *$Dvreview_t$* has no effect on the daily frequency. It increases variance and depreciates the exchange rate at the monthly frequency. This may be because Indian monetary policy announcements provide no guidance on the exchange rate beyond saying it is market determined, and the CB will intervene to prevent excess volatility[11]. The results imply an ineffective use of the communication channel with respect to the exchange rate since the statements or non-statements with respect to the exchange rate are increasing monthly volatility against the CB objectives. *$Dvreview_t$* affects the exchange rate but it is not used properly. As a result, the cluster variable *$comm_t$*, which measures the combined effect of *$speeches_t$* and d*$vreview_t$*, appreciates the daily exchange rate and decreases its variance, but has exactly the reverse effect at the monthly frequency[12].

The *$speeches_t$* dummy includes weights for when it is made and who makes it. Its significance therefore suggests that both timing and source matter. Timing matters as part of the *$speeches_t$* implies that RBI's future course of action triggers expectations and market actions.

Of the LAF interest rates, the reverse repo (*rev_t*, henceforth), which is the daily rate at which the CB absorbs liquidity from the market, works in the same direction as *$wtlafps_t$* to decrease daily variance (Table A3). This is intuitive since *rev_t* is the daily rate at which the CB absorbs liquidity from the market while *$wtlafps_t$* measures the actual absorption of daily liquidity. The LAF rates do not affect levels (Tables A4, A6), *rev_t* and *$repo_t$* have opposite effects on monthly variance, while the first continues to decrease it, the second (or the rate at which liquidity is injected into the money market) increases it (Table A5). But *rev_t* and *$repo_t$* significantly affect monthly variance only in a regression with all variables together, and not when each is taken alone with the control variables. Therefore the combined variable *$intrate_t$*, which has both the LAF rates together, is not significant.

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[11] Thus quoting from monetary policy announcements which is our d*$vreview_t$* variable, RBI (2003): "India's current exchange rate policy…has focused on the management of volatility without a fixed rate target and the underlying demand and supply conditions are allowed to determine the exchange rate movements over a period in an orderly way (pp.4)." RBI (2010) displays the continuity: "Our exchange rate policy is not guided by a fixed or pre-announced target or band. Our policy has been to retain the flexibility to intervene in the market to manage excessive volatility and disruptions to the macroeconomic situation (pp.9)."

[12] Egert (2007) points out that when actual and verbal communication comes together they increase the effectiveness of central bank actions. Fratzsher (2004) finds communication can be either a complement or a substitute for intervention. But in this case since the two act in opposite directions communication is not serving as either category.

The effect of interest rates on exchange rates comes through the control variable $intdiff_t$, which increases both daily and monthly variance and depreciates the monthly exchange rate. Since Indian call money rate (*cmr*) normally exceeds the federal funds rate (*ffr*), arbitraging inflows are expected to raise volatility. However, it is interesting to note that Indian capital account controls, including limits on bank open positions are unable to restrict arbitrage sufficiently to make the variable insignificant. The variable also depreciates the monthly exchange rate, while the UIP alone should imply appreciation. Thus implying that negative effects of high interest rates on growth may be dominating, reducing inflows and depreciating the exchange rate. Quantitative credit restrictions, higher interest differentials and policy lending rates maybe worsening prospects of the real economy.

The LAF policy rates largely influence exchange rates through their effects on *cmr*. Separate additional effects through the repo and reverse repo rates are minimal. The interest differential, which represents arbitrage opportunities and therefore induces markets to create liquidity, raises volatility in the short period as well as in the long run (Tables A3, A5). This implies that Indian regulatory restrictions to lower bank arbitrage in response to interest differentials are not effective.

Table 1: Summary of results

	Daily		Monthly	
	Variance	**Mean**	**Variance**	**Mean**
$quant_t$	-	-	-	-
$comm_t$		-	+	+
$wtlafps_t$	-	-		
$wtintvnet_t$			-	-
$dvacrr_t$	-		+	
$dvecrr_t$			+	
$speeches_t$	-	-		
$dvreview_t$			+	+
$dvnews_t$	-			
$intdiff_t$	+		+	+
$dvfomc_t$	+	-	-	
rev	-		(-)	
repo			(+)	

Note : The $dvnews_t$ and $speeches_t$ variables could not be constructed for the monthly frequency. $wtlafps_t$ is only for the daily frequency and $wtintvnet_t$ for monthly. The bracket ( ) indicates the variables were significant with all the dummy variables together but not alone with controls.

US monetary policy announcements have a large effect on Indian exchange rates, presumably through their effects on inflows and other market expectations. They increase daily variance and appreciate the daily exchange rate, but decrease monthly variance. Significant *$dvfomc_t$* gives support to Indian policy makers' worry that markets get too much influenced by US policy. The immediate impact raises volatility. But in the long run, at monthly frequency, as *$dvfomc_t$* policy actions become clearer and as market digests news then it tends to reduce volatility (Table A3, A5). It could be adjustments to the policy announcements are completed over the longer time period.

The control variables capture the environment in which the other policy actions have to operate. Although traditionally news is supposed to increase volatility in markets, Fišer and Horváth (2010) find that it reduces volatility in Czech Republic. They argue that since information is scarce in emerging markets news calms them. In our study also the sign of the coefficient on news (*$dvnews_t$*) is consistently negative. Therefore the creating news function of CB communication could also be reducing noise in emerging markets.

The results from putting the dummy variables in the mean equation are reported in Tables A4 and A6 for daily and monthly data respectively. Many of the dummy variables turn out to be significant in both the regressions, implying that despite contrary statements in monetary policy reviews RBI actions do affect the level of the exchange rate. The effects are summarized in Table 1.

4. Conclusion

In our tests of policy actions on exchange rate mean and volatility, using policy dummies in a GARCH framework, FX market intervention and communication outperform more traditional policy variables. This supports the Blinder et. al (2008) position that in a climate of uncertainty CB actions matter.

As a consequence of steady deepening of FX and money markets, while quantitative interventions continue to be important, communication can serve as a focal point, coordinating the actions of market participants (Sarno and Taylor, 2001). In particular, these variables allow the achievement of stated CB objectives either when interest rates alone have perverse effects because of differentials being affected by risk premia or when segmented domestic markets or asynchronous domestic cycles make it difficult to close the differentials.

Given that the stated CB objective is to reduce volatility, blunt quantitative actions such as cash reserves have perverse effects. A positive interest differential increases volatility and does not strengthen the long-run exchange rate. News tends to calm markets, suggesting that in emerging markets news may be at less than optimal levels. This greater uncertainty, combined with a credible CB, gives CB communication a lot of potential. But it is underutilized in our period of analysis. Communication and FX market intervention not only affect exchange rate volatility but also mean levels despite policy statements that there is no target exchange rate. It follows that policy makers would gain by investigating and evaluating the impact of alternative instruments, one by one and together. The communication channel needs to be further studied, developed, and used more intensively.

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Appendix A: Data sources

Interest rate differential- www.rbi.org.in and www.federalreserve.gov

Repo rate- www.reuters.com

Reverse rep rate- www.reuters.com

Cash reserve ratio (Announcement + effective implementation)- www.rbi.org.in

Liquidity adjustment facility-www.rbi.org.in

Speeches-www.rbi.org.in press releases

Timing-www.rbi.org.in archives

Federal open market committee meetings-www.federalreserve.gov

Macroeconomic news- www.mospi.nic.in

Appendix B: Descriptive statistics and correlation

Table A1a: Daily Descriptive Statistics

	mean	median	max	min	std dev	skewness	kurtosis	Jarque Bera test	probability
$lnex_t$	3.77	3.79	3.92	3.67	0.06	0.01	-0.96	44.44	0
$fdiff_t$	0.003	0	1.2	-1.44	0.17	0.08	12.56	7528.54	0
$dvacrr_t$	0.009	0	1	0	0.09	10.63	111.19	612595.6	0
$dvecrr_t$	0.01	0	1	0	0.11	8.62	72.46	265227.7	0
$wtlafps_t$	-0.23	0	2	-2	1.01	0.76	2.37	20	0
$dvrev_t$	0.003	0	1	0	0.06	16.94	285.49	3950434	0
$dvrep_t$	0.01	0	1	0	0.10	9.68	91.83	420985.6	0
$speeches_t$	0.23	0	4	0	0.73	3.33	10.01	7483.92	0
$dvreview_t$	0.01	0	1	0	0.10	9.68	91.83	420985.6	0
$dvnews_t$	0.23	0	1	0	0.42	1.26	-0.42	326.18	0
$intdiff_t$	2.45	1.76	35.2	-5.15	3.87	3.55	25.34	33108.35	0
$dvfomc_t$	0.03	0	1	0	0.16	5.87	35.40	57075.3	0

Note: $fdiff_t$ is first difference of $lnex_t$

Table A1b: Monthly Descriptive Statistics										
	lnex$_t$	***dvecrr$_t$***	***dvacrr$_t$***	***wtintvnet$_t$***	***dvrev$_t$***	***dvrep$_t$***	***fdiff$_t$***	***intdiff$_t$***	***dvreview$_t$***	***dvfomc$_t$***
mean	3.80	0.19	0.17	0.63	0.13	0.20	0.0001	3.21	0.25	0.69
median	3.81	0	0	1	0	0	-0.002	3.31	0	1
max	3.89	1	1	2	1	1	0.07	9.55	1	1
min	3.67	0	0	-2	0	0	-0.04	-4.53	0	0
Std dev	0.06	0.40	0.37	0.89	0.34	0.40	0.02	2.13	0.44	0.47
skewness	-0.55	1.61	1.82	-0.87	2.23	1.51	1.48	0.11	1.18	-0.82
kurtosis	2.61	3.49	4.20	3.20	5.79	3.19	8.60	3.28	2.33	1.68
JarqueBera	4.67	35.62	49.84	10.66	94.21	30.86	137.51	81.35	20.22	15.61
probability	0.10	0	0	0.0049	0	0	0	0	0.00004	0.0004

Table A2a: Daily Correlation Coefficients										
	dvacrr$_t$	***dvecrr$_t$***	***wtlafps$_t$***	***dvrev$_t$***	***dvrep$_t$***	***speeches$_t$***	***dvreview$_t$***	***dvnews$_t$***	***intdiff$_t$***	***dvfomc$_t$***
dvacrr$_t$	1.00									
dvecrr$_t$	-0.01	1.00								
wtlafps$_t$	0.02	-0.03	1.00							
dvrev$_t$	-0.006	-0.007	-0.04	1.00						
dvrep$_t$	0.27	-0.01	0.03	0.43	1.00					
speeches$_t$	0.06	-0.03	-0.08	-0.02	0.003	1.00				
dvreview$_t$	0.36	-0.01	-0.03	0.28	0.33	-0.03	1.00			
dvnews$_t$	-0.008	0.21	0.09	0.002	0.02	-0.04	-0.02	1.00		
intdiff$_t$	0.11	0.03	0.40	-0.01	0.09	0.0004	-0.02	0.02	1.00	
dvfomc$_t$	0.10	-0.02	-0.05	-0.01	0.09	-0.04	0.09	-0.003	0.03	1.00

Table A2b: Monthly Correlation Coefficients								
	dvecrr$_t$	***dvacrr$_t$***	***wtintvnet$_t$***	***dvrev$_t$***	***dvrep$_t$***	***intdiff$_t$***	***dvreview$_t$***	***dvfomc$_t$***
dvecrr$_t$	1.00							
dvacrr$_t$	0.35	1.00						
wtintvnet$_t$	0.03	-0.03	1.00					
dvrev$_t$	-0.008	-0.07	-0.12	1.00				
dvrep$_t$	0.21	0.09	-0.33	0.24	1.00			
intdiff$_t$	0.24	0.18	-0.28	-0.06	0.33	1.00		
dvreview$_t$	.07	0.26	-0.10	0.27	0.11	-0.14	1.00	
dvfomc$_t$	0.0625	0.0921	-0.11	-0.12	0.15	0.1	-0.27	1.00

Appendix C: Results

$$\Delta \ln ex_t = c + \sum_{i=1}^{3} \phi_i \, \Delta \ln ex_{t-i} + \varepsilon_t \qquad \sigma_t^2 = \alpha + \beta\varepsilon_{t-1}^2 + \gamma\sigma_{t-1}^2 + \delta_i \sum_{i=1}^{11} CB_{it} + \lambda_1 \, \mathrm{int}diff_t + \lambda_2 news_t$$

$$0 < |\phi| < 1 \text{ , } \alpha > 0, \;\; \beta \geq 0, \;\; \gamma \geq 0, \;\; \beta + \gamma < 1, \sigma_t^2 \geq 0$$

Table 3: Variance- daily

	1	**2**	**3**
α	0.002***	0.0012***	0.003***
	(0.001)	(0.00013)	(0.0002)
β	0.08***	0.11***	0.084***
	(0.02)	(0.012)	(0.012)
γ	0.90***	0.87***	0.888***
	(0.02)	(0.01)	(0.013)
δ $_1$(comm$_t$)	-0.0007***		
	(0.0002)		
δ $_2$(quan$_t$)	-0.00033**		
	(0.0002)		
δ $_3$(intrates)	-0.002		
	(0.004)		
δ $_4$(wtlaffps)			-0.0004***
			(0.0001)
δ $_5$(dvacrr$_t$)			-0.009**
			(0.004)
δ $_6$(dvecrr$_t$)			0.0043
			(0.004)
δ $_7$(dvrep$_t$)			0.004
			(0.006)
δ$_8$(dvrev$_t$)		-0.007***	-0.015*
		(0.001)	(0.008)
δ$_9$(speeches$_t$)			-0.0008**
			(0.0004)
δ$_{10}$(dvreview$_t$)			0.003
			(0.005)
δ$_{11}$(dvfomc$_t$)	0.007*	0.005***	0.006*
	(0.0037)	(0.001)	(0.003)
λ$_1$***(intdiff$_t$)***	0.0002***	4.66E-05***	0.0002***
	(4.08E-05)	(1.61E-05)	(3.74E-05)
λ$_2$***(dvnews$_t$)***	-0.008***	-0.004***	-0.008***
	(0.002)	(0.0003)	(6.19E-05)
L-B(10), STD RES	6.628	5.523	6.118
L-B(20), STD RES	30.252	22.113	26.134
SIC	-1.077	-1.222	-1.083
N	1157	1157	1157

Note: Standard errors (in parentheses), Ljung Box Q-statistics of the tenth lag of residuals and squared residuals are reported. ***,** and * denotes significance at 1%,5% and 10% level.

Table 4: Mean- daily data				
	1	**2**	**3**	**4**
c	0.003	-0.003	0.005	0.0006
	(0.004)	(0.003)	(0.004)	(0.004)
ϕ_1	0.044	0.048	0.048	0.046
	(0.033)	(0.032)	(0.033)	(0.032)
ϕ_2	-0.016	-0.016	-0.014	-0.015
	(0.036)	(0.036)	(0.040)	(0.036)
ϕ_3	-0.049	-0.053	-0.050	-0.053
	(0.039)	(0.039)	(0.039)	(0.039)
$\delta_1(comm_t)$				-0.010***
				(0.003)
$\delta_2(quan_t)$				-0.005*
				(0.003)
$\delta_3(intrates)$				-0.008
				(0.030)
δ_4(**wtlaffps**)	-0.004^0	-0.004*		
	(0.003)	(0.002)		
$\delta_5(dvacrr_t)$	0.008			
	(0.090)			
$\delta_6(dvecrr_t)$	0.007			
	(0.399)			
$\delta_7(dvrep_t)$	-0.028			
	(0.042)			
$\delta_8(dvrev_t)$	0.076			
	(0.105)			
$\delta_9(speeches_t)$	-0.010***		-0.010***	
	(0.0035)		(0.004)	
$\delta_{10}(dvreview_t)$	-0.033			
	(0.090)			
$\delta_{11}(dvfomc_t)$	-0.0201		-0.026*	-0.026*
	(0.016)		(0.015)	(0.015)
$\lambda_1(intdiff_t)$	-7.13E-05		-0.0007	
	(0.0008)		(0.00078)	
$\lambda_2(dvnews_t)$	-0.008		-0.009	
	(0.008)		(0.008)	
L-B(10), STD RES	5.843	7.070	6.032	6.207
L-B(20),STD RES	24.738	25.761	25.054	25.963
SIC	-1.194	-1.201	-1.189	-1.190
N	1157	1157	1157	1157

Note: Standard errors (in parentheses), Ljung Box Q-statistics of the tenth lag of residuals and squared residuals are reported. ***,** and * denotes significance at 1%,5% and 10% level, ^{0} weakly significant, p-value [0.146]. In regression 2 with controls, $wtlafps_t$ and controls are not significant, so controls are dropped.

$$\Delta \ln ex_t = c + \phi \Delta \ln ex_{t-1} + \varepsilon_t \qquad \sigma_t^2 = \alpha + \beta \varepsilon_{t-1}^2 + \gamma \sigma_{t-1}^2 + \delta_i \sum_{i=1}^{n} CB_{it} + \lambda_1 \, intdiff_t$$

Table 5: Variance- monthly

	1	**2**	**3**	**4**	**5**	**6**	**7**
α	-2.82E-05	-4.07E-05***	7.89E-05**	-3.47E-05	-4.07E-05***	9.45E-05***	9.03E-05***
	(3.93E-05)	(9.84E-06)	(3.15E-05)	(8.34E-05)	(9.84E-06)	(3.00E-05)	(1.57E-05)
β	0.046	0.073	0.3189***	0.0002	0.073	0.553***	0.784***
	(0.126)	(0.054)	(0.111)	(0.113)	(0.054)	(0.180)	(0.196)
γ	0.787***	0.883***	0.709***	0.778***	0.883***	0.503***	0.124**
	(0.249)	(0.048)	(0.116)	(0.198)	(0.048)	(0.094)	(0.052)
δ₁(comm_t)	0.0002*	0.000198***					
	(9.07E-05)	(6.02E-05)					
δ₂(quan_t)	6.17E-06		-5.97E-06^{0}				
	(1.45E-05)		(3.74E-06)				
δ₃(*intrates*)	-2.49E-05						
	(4.60E-05)						
δ₄(*wtintvnet_t*)				-9.39E-06		-3.85E-05***	
				(1.67E-05)		(5.08E-06)	
δ₅(dvacrr_t)				-8.91E-05			0.00047***
				(9.95E-05)			(0.00014)
δ₆(dvecrr_t)				0.00011			
				(8.76E-05)			
δ₇(dvrep_t)				7.59E-05***			
				(1.17E-05)			
δ₈(dvrev_t)				-0.00012**			
				(6.36E-05)			
δ₉(*dvreview_t*)				0.00016**	0.000198***		
				(8.42E-05)	(6.02E-05)		
δ₁₀(*dvfomc_t*)	-3.19E-05	-7.06E-05**	-0.00013***	-5.82E-06	-7.06E-05**	-0.000130***	-7.22E-05***
	(2.66E-05)	(3.41E-05)	(2.93E-05)	(8.78E-05)	(3.41E-05)	(2.86E-05)	(3.03E-06)
λ₁(intdiff_t)	2.17E-05**	2.08E-05***	1.20E-05***	1.75E-05**	2.08E-05***	1.82E-05***	-4.27E-06
	(9.92E-06)	(5.91E-06)	(1.64E-06)	(7.18E-05)	(5.91E-06)	(3.75E-06)	(4.71E-06)
L-B(10), STD RES	8.374	6.077	7.705	6.714	6.077	9.08	8.888
L-B(20), STD RES	26.050	25.204	27.622	21.448	25.204	24.78	26.702
SIC	-5.020	-5.533	-5.554	-5.318	-5.533	-5.665	-5.723
N	84	84	84	84	84	84	84

Note: Standard errors (in parentheses), Ljung Box Q-statistics of the tenth lag of residuals and squared residuals are reported. ***,** and * denotes significance at 1%,5% and 10% level. ^{0} weakly significant, p-value [0.111]. If regression 3 is done without controls *quant*$_t$ is strongly significant and positive.

Table 6: Mean- monthly data				
	1	**2**	**3**	**4**
c	-0.004*	-0.0026	0.001	-0.004***
	(0.002)	(0.0035)	(0.001)	(0.002)
ϕ	0.326***	0.226**	0.264***	0.383*
	(0.085)	(0.109)	(0.077)	(0.013)
δ_1(comm$_t$)	0.005**			
	(0.002)			
δ_2(quan$_t$)	-0.003***			
	(0.001)			
δ_3(intrates)	-0.0005			
	(0.001)			
δ_4(wtintvnet$_t$)		-0.005***	-0.005***	
		(2.58E-05)	(0.001)	
δ_5(dvacrr$_t$)		-0.001		
		(0.003)		
δ_6(dvecrr$_t$)		-0.001		
		(0.003)		
δ_7(dvrep$_t$)		-0.0003		
		(0.002)		
δ_8(dvrev$_t$)		-0.0003		
		(0.003)		
δ_9(dvreview$_t$)		0.004*		0.005***
		(0.003)		(0.001)
δ_{10}(dvfomc$_t$)	0.002	0.001	-0.002	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
λ_1(intdiff$_t$)	0.001***	0.001*	0.0009***	0.0004
	(1.10E-06)	(0.001)	(4.31E-05)	(0.001)
L-B(10), STD RES	9.765	11.576	11.561	7.074
L-B(20), STD RES	28.421	31.876	30.296	22.542
SIC	-5.820	-5.800	-6.003	-5.908
N	84	84	84	84

Note: Standard errors (in parentheses), Ljung Box Q-statistics of the tenth lag of residuals and squared residuals are reported. ***,** and * denotes significance at 1%,5% and 10% level.