

# **Zone-quadratic Preference, Asymmetry and International Reserve Accretion in India: An Empirical Investigation**

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## **Abstract**

Empirical estimates of the Reserve Bank of India's (RBI) intervention reaction function suggest that the central bank actively intervenes in the foreign exchange market to contain volatility but this intervention is neither continuous nor linear. It is better described by a nonlinear policy reaction function with a target range as opposed to a point target. It responds much more vigorously to appreciating or depreciating pressure outside the target range but the response is much more muted within the range. Moreover, the tolerance band is asymmetric i.e., the RBI responds much more strongly to appreciating pressure than depreciating pressure. Such a policy response in an era of continuous net capital inflows accounts for the large build-up in foreign exchange reserves witnessed in India in the recent past.

*JEL Classifications:* E52; E58; F31; F33; F41

*Keywords:* International Reserves; Monetary policy; Exchange rate; Target range; Asymmetry

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# Zone-quadratic Preference, Asymmetry and International Reserve Accretion in India: An Empirical Investigation

## 1. Introduction

According to official pronouncements India moved away from a fixed exchange rate regime to a market determined exchange rate regime in March 1993.<sup>1</sup> Nevertheless, the Reserve Bank of India (RBI) actively intervenes in the foreign exchange market with the goal of containing volatility, and influencing the market value of the exchange rate. Furthermore, as the then RBI governor Reddy (1997) argues, “In the context of large capital flows (inflows as well as outflows) within a short period, it may not be possible to prevent movements in the exchange rate away from the fundamentals. Hence, the management of exchange rate fluctuations become passive i.e., one of preventing undue appreciation in the context of large inflows and providing a supply of dollars in the market to prevent sharp depreciation.”

The above quotation suggests that the RBI would not be willing to tolerate *undue* fluctuations in exchange rate but would be willing to accommodate *moderate* appreciation or depreciation. That is, when there is excessive depreciation of the domestic currency (owing to large capital outflows) the RBI may try to reduce the rate of depreciation. Similarly, when there is excessive appreciation of the domestic currency (owing to capital inflows) the central bank may try to dampen the rate of

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<sup>1</sup> The exchange rate policy has evolved from the rupee being pegged to the pound sterling until 1975, pegged to an undisclosed currency basket until 1992 and after a year's experience with dual exchange rate system to a market-based system by March 1993 (Reddy, 1997).

appreciation. Moderate appreciation or depreciation may not elicit a policy response.<sup>2</sup>

This raises several questions. i) What is the range of tolerance (zone of inaction/ comfort zone) for fluctuations in the exchange rate? ii) What is the width of this zone? iii) Is the policy response symmetric to appreciating and depreciating pressure?

In order to examine whether the RBI has a target range as opposed to a point target we employ a modified quadratic loss function for its exchange rate objective. The standard quadratic loss function is a special case of this model. The preference specification we use is analytically tractable and yields a reduced-form solution for the policy instrument i.e., central bank intervention in the foreign exchange market.<sup>3</sup>

The key feature of our specification is that it allows policymakers to react differently depending on whether the exchange rate is within or outside their comfort zone.

This in turn is estimated in order to evaluate its empirical likelihood.

To anticipate our result, we find that the RBI actively intervenes in the foreign exchange market but this intervention is neither continuous nor linear. It is better

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<sup>2</sup> A target range as opposed to a point target for the exchange rate gives a clear message to the market participants that the central bank has imperfect control over the exchange rate. Moreover, a range gives policymakers' more flexibility to accommodate moderate variations in the exchange rate, thereby preserving flexibility in exchange rate management. This also gives the central bank sufficient leeway to pursue objectives other than exchange rate management.

<sup>3</sup> There is by now a large literature on monetary policy reaction functions, which focuses on how monetary authorities adjust interest rates in response to goal variables. Our focus is, however, specifically on reaction functions designed to examine exchange rate management (Sarno and Taylor, 2001). Thus, intervention in the foreign exchange market is our policy instrument.

described by a nonlinear reaction function with a zone of inaction. It responds much more vigorously to appreciating or depreciating pressure outside this comfort zone but the response is much more muted within the zone. Moreover, the tolerance band is asymmetric i.e., the RBI responds much more strongly to appreciating pressure than to depreciating pressure. This behaviour in turn accounts for the surge in foreign exchange reserve witnessed in India in the recent past.<sup>4</sup>

Rest of the paper is organised as follows. Section 2 presents the model and derives an intervention reaction function as the first-order condition of the central bank's optimization problem. The reaction function allows policymakers to react differently depending on whether the exchange rate is within or outside their comfort zone. Section 3 discusses the data, methodology used for testing the model, and discusses the empirical results for our benchmark model. Section 4 discusses the strategy followed to estimate the width of the zone of inaction/ comfort zone and reports our findings. Section 5 concludes.

## **2. Theoretical framework**

There is a large literature on monetary policy reaction function which focuses on how the central bank adjusts interest rate in response to goal variables. However,

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<sup>4</sup> The surge in international reserves holding among emerging market economies has attracted considerable attention in the recent past since much of the foreign capital flowing into the United States has come from foreign central banks, which have allowed the U.S. current account deficit to be financed at prevailing asset prices and exchange rates (Summers, 2006).

our focus here is on reaction function designed specifically to examine exchange rate management (Almekinders and Eijffinger (1996) and Sarno and Taylor (2001)). In what follows central bank intervention in the foreign exchange market is our policy instrument. In our benchmark framework we assume that we are dealing with a static (or one shot) model. The standard quadratic loss function for exchange rate objective is given by:

$$L = \frac{(I - I^*)^2}{2} + \frac{\lambda(\tilde{e} - \tilde{e}^*)^2}{2}, \quad (1)$$

where,  $\lambda > 0$  is the relative weight placed on exchange rate stabilization.<sup>5</sup> Here  $\tilde{e}$  is the percentage change in (nominal) exchange rate defined as domestic price of one unit of foreign currency and  $\tilde{e}^*$  is the target.<sup>6</sup>  $I$  is the volume of intervention (policy instrument) defined as purchases of foreign currency by the domestic central bank and  $I^*$  is the optimal level of intervention, assumed constant.

The standard quadratic specification gives equal weight to appreciating and depreciating pressure around a point target. The specification does not allow us to

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<sup>5</sup> The traditional approach to the estimation of intervention equation has often been criticized because of the *ad hoc* specification typically employed by this literature. More recently, Almekinders and Eijffinger (1996) obtain an intervention reaction function by combining an exchange rate model with a particular loss function for the central bank. A similar strategy is followed here.

<sup>6</sup> In what follows we assume that  $\tilde{e}^* = 0$  as RBI does not announce a predetermined target (or band) for the exchange rate. Ideally, we should use the deviation of real exchange rate from target. Instead, nominal exchange rate is used in our analysis. The reason is, monitoring the nominal exchange rate, as opposed to the real exchange rate, has been the official policy. For example, the former Governor of the RBI, Jalan (1999) states: “From a competitive point of view and also in the medium term perspective, it is the REER, which should be monitored as it reflects changes in the external value of a currency in relation to its trading partners in real terms. However, it is no good for monitoring short-term and day-to-day movements as ‘nominal’ rates are the ones which are most sensitive of capital flows. Thus, in the short run, there is no option but to monitor the nominal rate.”

capture the possibility of zone of inaction or target range. In order to examine whether the RBI has a target range as opposed to a point target, we employ a modified quadratic logistic function for its exchange rate objective and assume the usual quadratic functional form for its instrument (Srinivasan et al. (2006)).<sup>7</sup> Thus, our modified loss function is:

$$L = \frac{(I - I^*)^2}{2} + \frac{\lambda(\tilde{e} - \tilde{e}^*)^2}{1 + \exp(-a[(\tilde{e} - \tilde{e}^*)^2 - \eta])}, \quad (2)$$

where,  $a > 0$  dictates the width of the target range and  $\eta$  is a constant parameter. Note that as  $a \rightarrow 0$  the period loss function (eq. 2) collapses to the usual quadratic case i.e., the function exhibits the usual quadratic form as a special case.

Figure 1 plots the modified loss function. We assume  $a = 15$  and  $\eta = 7$  for the purpose of illustration. Here the dashed line is the loss for zone quadratic preference whereas the solid line represents the loss for a standard quadratic specification ( $a = 0$ ). For these parameter values ( $a = 15$  and  $\eta = 7$ ) the modified loss function is the standard quadratic function outside the zone, but collapses (discontinuously) to zero within the zone boundary. In other words, small deviations of the goal variable within the zone boundary are tolerated, whereas large deviations are heavily penalized. Such preferences imply that when appreciating or depreciating pressure

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<sup>7</sup> See Orphanides & Wieland (2000) and Minford & Srinivasan (2006) for further details on the rationale behind zone-quadratic preferences in the context of inflation stabilization.

is within the comfort zone, policymakers respond much less forcefully than when it is outside the zone.

In order to understand the implications of such preferences for optimal policy we solve the policymaker's optimization problem maintaining the assumption of a linear structure for its constraint. We assume that the intervention by central bank in the foreign exchange rate market can dampen the rate of appreciation or depreciation.<sup>8</sup> That is,

$$\tilde{e} - \tilde{e}^* = b_0 + b_1 I + \varepsilon, \quad (3)$$

where,  $b_1 > 0$  and  $\varepsilon \sim iid(0, \sigma_\varepsilon^2)$ .

Minimising (2), by choosing  $I$  subject to the constraint (3) yields the following first-order condition:

$$0 = (I - I^*) + \frac{\lambda \{2b_1 \tilde{e} (1 + \exp(-a(\tilde{e}^2 - \eta))) + 2ab_1 \tilde{e}^3 \exp(-a(\tilde{e}^2 - \eta))\}}{[1 + \exp(-a(\tilde{e}^2 - \eta))]^2}. \quad (4)$$

Our task involves estimating this non-linear reaction function in order to evaluate whether the parameter ' $a$ ' is significantly different from zero. Thus testing for  $a = 0$  will help us discriminate between the zone quadratic and quadratic specification. In

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<sup>8</sup> Whether or not official intervention is effective in influencing the exchange rate is an issue of crucial policy importance, and have been subject to a vast academic literature (see Edison (1993) for a survey). These issues are beyond the scope of this paper.

order to simplify things we linearize equation (4) by means of a first-order Taylor series expansion around  $a = 0$  which yields:<sup>9</sup>

$$I = \alpha_0 + \alpha_1 \tilde{e} + \alpha_2 (\tilde{e})^3, \quad (5)$$

where,  $\alpha_0 = I^*$ ,  $\alpha_1 = -\lambda b_1 \left(\frac{2-a\eta}{2}\right)$  and  $\alpha_2 = -a\lambda b_1$ .

Note that, the cubic term in exchange rate enters equation (5) if and only if  $a \neq 0$  i.e., policymakers have zone-quadratic preference. If  $a = 0$ , then we have the standard linear response to exchange rate fluctuation i.e., lean-against-the-wind policy. Figure 2 plots the intervention reaction function for the zone-quadratic model. The dotted line is the policy response to exchange rate fluctuation. Notice that the policy response is muted when the rate of appreciating/ depreciating pressure is within the comfort zone but much more forceful outside the zone. Thus, in the reduced form equation above, ' $\alpha_2$ ' is the coefficient which embodies the information about zone quadratic preference, so that the restriction,  $a = 0$ , implies,  $\alpha_2 = 0$ . Hence testing for  $H_0: \alpha_2 = 0$  is equivalent to testing for  $a = 0$ . We now proceed to empirically evaluate our model.

### 3. Data and Methodology

#### 3.1 Data

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<sup>9</sup> First-order Taylor series expansion of a function  $f(a)$  around  $a = 0$  is,  $f(a) = f(0) + f'(0) * a$ . Here we have  $f(0) = \lambda b_1 \tilde{e}$  and  $f'(0) = \lambda \tilde{e}^3 - \lambda \left(\frac{b_1 \eta}{2}\right) \tilde{e}$ .



Intervention data is not available at high frequency for India, so we use percentage change in foreign exchange reserves as its proxy (Srinivasan et al., 2009).<sup>10</sup> We replace  $I_t$  by percentage change in foreign exchange reserves  $\tilde{R}_t = (\Delta \log R_t) * 100$  in equation (5). The percentage change in exchange rate is defined as  $\tilde{e}_t = (\Delta \log e_t) * 100$ , where  $e_t$  is domestic price of one unit of foreign currency.

Thus, our reduced form model is given by:

$$\tilde{R}_t = \alpha_0 + \alpha_1 * (\tilde{e}_{t-1}) + \alpha_2 * (\tilde{e}_{t-1})^3 + \vartheta_t, \quad (6)$$

where,  $\alpha_0 = \tilde{R}^*$ ,  $\alpha_1 = -\lambda b_1 \left(\frac{2-a\eta}{2}\right)$ ,  $\alpha_2 = -a\lambda b_1$  and  $\vartheta_t$  is the error term.

Data are collected from the Handbook of statistics on the Indian Economy published by the RBI. We use weekly data for the Rs/US\$ exchange rate and foreign exchange reserve for the period November 2000 to August 2010 since there has been a steep rise in reserve accumulation during this period.<sup>11</sup>

### 3.2 Methodology

We use Generalised Method of Moments (GMM) to estimate the reduced form equation. The GMM approach is very appealing, because it does not require strong assumptions concerning the distribution of shocks. In fact, it only requires

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<sup>10</sup> We realize that changes in reserves represent a crude proxy for intervention activity since reserves may change for a number of reasons and often not related to official intervention. Reserves increase, for example, with valuation changes on existing reserves. Our results are subject to these data limitations.

<sup>11</sup> The gold stock, SDRs and Reserve Tranche Position held with the IMF are not included, as they constitute a very negligible proportion of foreign reserves and are not used as an intervention asset.

identifying relevant instrument variables, strongly correlated with the independent variables, but uncorrelated with innovations. GMM estimators have been shown to be strongly consistent and asymptotically normal (Hansen, 1982).

We need to avoid choosing a large number of instruments as there is a strong variance/bias trade off as the number of instruments is increased. Larger number of instruments means including more moment restrictions (more information) which improve the estimation performance, but in small samples it comes at the cost of precision of the estimated weighting matrix. In this regard Hansen (1982) over-identifying restriction test (J-statistics) is used to decide the optimal set of instruments. A rejection of these restrictions would indicate that some of the variables in the information set fail to satisfy the orthogonality conditions.<sup>12</sup>

### 3.3 Testing for comfort zone or zone of inaction

We use GMM estimator with an optimal weighting matrix that accounts for possible heteroscedasticity and serial correlation in the error terms. We employ a twelve lag Newey–West estimate of the covariance matrix. Ten lags of  $\tilde{R}_t$ , nine lags of  $\tilde{e}_{t-1}$  and  $(\tilde{e}_{t-1})^3$ , and current value of U.S. federal funds rate and its ten lags are used as instruments.<sup>13</sup> This corresponds to a set of 39 over-identifying restrictions.

The estimates are produced in Table 1. The J-statistic indicates that the null

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<sup>12</sup> The minimised distance J-statistics (value of the objective function in GMM estimation) is asymptotically distributed as a chi-squared with  $(q - n)$  degrees of freedom, where  $q$  is the number of instruments used,  $n$  is the number of independent variables and  $q \geq n$ .

<sup>13</sup> We use federal funds rate as a proxy for foreign interest rate, which is used as instrument in GMM estimation. This data is collected from the FRED database at the Federal Reserve Bank of St. Louis.

hypothesis of valid over-identifying restrictions cannot be rejected at conventional significance level. That is, there are no invalid instruments used in the estimation. Notice that the coefficient associated with the cubic term is significant at 1% level of significance with the expected sign. That is, the null of  $\alpha_2 = 0$  is rejected with p-value 0. Thus,  $a \neq 0$  i.e., there is evidence for a target range as opposed to a point target for the exchange rate. In sum estimates from our benchmark model suggests that the RBI intervenes in the foreign exchange market but this intervention is neither continuous nor linear.

Having said that, it must be emphasized here that although our benchmark model estimated here can help us to formally evaluate whether the RBI has a zone of inaction (or tolerance band) or not, it cannot however tell us what the width of this zone is. The next section outlines the framework that we use for estimating the width of the zone of inaction.

#### **4. Estimating the width of the zone of inaction**

In order to determine the width of the zone, we follow Tachibana (2006, 2008). We start with a linear policy reaction function in order to facilitate comparison. The policy instrument  $\tilde{R}_t$  is expressed as a linear function of the goal variable,  $\tilde{e}_{t-1}$ , i.e.,

$$\tilde{R}_t = c + \beta(\tilde{e}_{t-1}) + \mu_t, \quad (7)$$

where,  $c = R^*$ ,  $\beta = -\lambda b_1$  and  $\mu_t$  is the error term.<sup>14</sup> Linearity implies that policy response is symmetric. We relax this assumption by introducing a zone of inaction (or target range) which allows for different values of ' $\beta$ ' depending on the magnitude of the change in exchange rate. Tachibana (2006) introduces dummy variable, which takes different values depending on whether inflation is within or outside the comfort zone, in a linear Taylor rule specification, to capture the presence of a zone of inaction for inflation. We use his formulation to capture the comfort zone for exchange rate. To do so, the linear policy reaction function in equation (7) is reformulated so that the policy response coefficient ( $\beta$ ) takes different values depending on whether the goal variable (exchange rate) lies inside or outside the tolerance threshold. Thus, we have

$$\tilde{R}_t = c + \beta^{OZ}(\tilde{e}_{t-1}) + (\beta^{IZ} - \beta^{OZ}) * D_{t-1} * \tilde{e}_{t-1} + \vartheta_t, \quad (8)$$

where,  $D_t$  is a dummy variable which takes a value of one if the percentage change in the exchange rate is within the zone and a value of zero when it is outside the zone. Here  $\beta^{OZ}$  captures the policy response if the goal variable overshoots or undershoots the zone, and  $\beta^{IZ}$  captures the response when exchange rate lies within the zone boundary. If the policy response outside the zone boundary is much more forceful, then we would expect,  $|\beta^{OZ}| > |\beta^{IZ}|$ . If  $\beta^{OZ} = \beta^{IZ} = \beta$ , then equation (8) collapses into a linear reaction function.

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<sup>14</sup> This is a policy rule without a comfort zone i.e., a special case of the benchmark model, where  $a = 0$ .

Thus, estimating equation (8) enables us to test the linear specification against the nonlinear specification. Moreover, recent studies on India have reported that the RBI treats appreciating and depreciating pressure differently. That is, the response to appreciating pressure is much more forceful than to depreciating pressure of the same magnitude (Ramachandran and Srinivasan (2007) and Srinivasan et al. (2009)). The model used here is sufficiently flexible and allows us to test for such asymmetries.

#### **4.1 Methodology for estimating the width of the zone of inaction**

The problem in estimating equation (8) is that we do not know what the exchange rate target range is. The RBI does not explicitly state the width of its inaction zone. In fact, it claims that it neither has a point target nor a target range for the exchange rate. So we indirectly estimate the RBI's implicit zone of inaction using the methodology adopted by Tachibana (2006). Once we know the implicit zone, the coefficients of equation (8) can be directly estimated by GMM.

We proceed as follows. We create a number of candidates for the 'true' target zone in the range of the data. Maximum depreciation is 1.7% and appreciation is -2.1% in the sample. Various possible pairs between the range -2.2 and 1.8 are considered as candidate zones. All the possible combinations falling in this range up to one decimal point are considered. As a limiting case, if the zone of inaction is  $[-2.2, +1.8]$ , then there is no intervention during the whole sample period, and if its width is 0, it means there is no zone of inaction and central bank intervenes

continuously in the foreign exchange rate market (quadratic loss with a point target).

The actual zone of inaction must lie somewhere in between these two limiting cases.

GMM estimation of equation (8) is repeatedly run for each of these candidate target zones.<sup>15</sup> The Likelihood-Ratio (LR) test statistic for the null hypothesis,  $\beta^{OZ} = \beta^{IZ} = \beta$  (linear specification) is calculated.<sup>16</sup> The maximum LR test statistics is selected from the estimates satisfying,  $|\beta^{OZ}| > |\beta^{IZ}| \geq 0$ , since it is counter-intuitive to consider the case where response outside the zone is less forceful than that within the zone. Among the candidate zones considered, the one that generates the maximum LR test statistics is regarded as the “true” zone of inaction.

## 4.2 Results and Analysis

Model (7), which is a special case of the model (8), where  $\beta^{OZ} = \beta^{IZ} = \beta$ , is the restricted model. The GMM estimation of model (8), which is the unrestricted model, is run for all the candidate zones created. Values of the objective function from the efficient GMM estimates for these two models are collected and the LR-statistics is calculated. The candidate zone with maximum value of the LR-statistics is taken as the true zone of inaction. Based on this criterion,  $[-0.4\%, +1.1\%]$  is the zone of inaction for the RBI during the sample period. That is, the RBI can tolerate 1.1%

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<sup>15</sup> Twelve lags of  $\tilde{R}_t$ , eleven lags of  $\tilde{e}_{t-1}$  and  $(D_{t-1} * \tilde{e}_{t-1})$ , and current value of the federal funds rate and its twelve lags are used as instruments corresponding to a set of 46 over-identifying restrictions.

<sup>16</sup> Although value of the objective function used for calculating the Likelihood-Ratio (LR) test here is not the value of any likelihood function, we term it as LR test in line with Hayashi (2000). LR test statistics, calculated as 'n' times the difference between the J-statistics from the restricted efficient GMM and the unrestricted efficient GMM, is asymptotically chi-squared distributed (for detail see Hayashi (2000)), where 'n' is the number of observation.

depreciation of the domestic currency but can only tolerate 0.4% appreciation on a week-on-week basis.

Results for the restricted model (eq. 7) are reported in table 2 while estimates for the unrestricted model are reported in table 3. The J-statistics test for the null of valid over-identifying restriction is not rejected suggesting that the instrument set used is valid. LR test statistics is used to test for the null of,  $H_0: \beta^{OZ} = \beta^{IZ}$ . It rejects the null that is,  $\beta^{OZ} \neq \beta^{IZ}$ , i.e., the nonlinear specification is superior to the linear specification. This would suggest that there is neither continuous nor linear intervention in the foreign exchange rate market.

Moreover, table 3 suggests that policy response (i.e., intervention) is much more forceful when the goal variable overshoots/ undershoots the zone of inaction. Policy response within the zone,  $\beta^{IZ}$  is not significantly different from zero i.e., when appreciating/ depreciating pressure is moderate there is no policy response. Policy response outside the zone  $\beta^{OZ}$  is highly significant, with the appropriate sign.

Figure 3 plots the policy response coefficient when exchange rate is within or outside the zone of inaction from our estimates. X-axis plots percentage change in exchange rate while the Y-axis depicts percentage change in reserves. The solid line depicts the policy response to exchange rate fluctuations and the dashed lines are 95% standard error (SE) band. The SE band tells us the extent of uncertainty surrounding our estimates. The standard error bands for within zone response ( $\beta^{IZ}$ ) is wider than the response outside the zone ( $\beta^{OZ}$ ), meaning this parameter is less precisely estimated.

Moreover, the within zone SE band includes zero slope, suggesting that the estimates are not significantly different from zero. Also note, slope of the policy response coefficient is steeper outside the zone. That is, there is a stronger response outside the zone than within the zone.

Interestingly, note that the width of the range of inaction or comfort zone is not symmetric. That is, the tolerance level for appreciating pressure is much lower than that for depreciating pressure. As pointed out earlier, the RBI seems to be comfortable with 1.1% depreciation but can tolerate only 0.4% appreciation of the domestic currency. As a result, there is a rise in reserve demand in response to capital inflows (appreciating pressure) whereas the reserves do not fall significantly in response to capital outflows (depreciating pressure). In sum, aggressive purchase of foreign currency in response to appreciating rupee, triggered perhaps by concerns about India's export competitiveness, and muted response to depreciating pressure seems to have contributed to a large stockpile of reserves.

Finally, we examine the superiority of our specification *vis-a-vis* other models. We use the predictive accuracy test suggested by Diebold and Mariano (1995) to examine the predictive accuracy of competing models. Srinivasan et al. (2009) employ an asymmetric preference specification for exchange rate objective as opposed to our zone-quadratic specification to account for reserve accretion in



India.<sup>17</sup> The predicted values of the percentage change in reserves are constructed using these models and mean square error (MSE) is calculated. The MSE of the model with zone specification (0.283) is lower than the MSE of the competing model (0.353). The predictive accuracy test suggested by Diebold & Mariano (1995) rejects the null hypothesis that two competing models have equal forecast accuracy (p-value: 0.049). In other words, forecast accuracy of the zone-quadratic model is superior.

## 5. Conclusion

This paper examines the conduct of exchange rate policy in India. Estimate from an intervention reaction function suggests that exchange rate policy can be characterized by a nonlinear policy rule. Specifically, we find evidence for a target range as opposed to a point target for changes in exchange rate. That is, the RBI intervenes in the foreign exchange market to contain volatility but this intervention is neither continuous nor linear. It is better described by a nonlinear reaction function with a zone of inaction. It responds much more vigorously when there is pressure on exchange rate to overshoot or undershoot the target range but the response is much more muted when the exchange rate is within the zone boundary.

Furthermore, the width of the zone of inaction is asymmetric i.e., the tolerance level

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<sup>17</sup> The asymmetric preference specification employed by Srinivasan et al. (2009) for exchange rate objective in the central bank loss function along with linear constraint (eq. 3) implies the following reduced form reaction function:  $\tilde{I} = C_1 + C_2 * \tilde{e} + C_3 * (\tilde{e})^2$ . For comparative analysis we estimated this model using GMM. Twelve lags of  $\tilde{R}_t$ , eleven lags of  $\tilde{e}_{t-1}$  and  $(\tilde{e}_{t-1})^2$ , current value of the federal funds rate and its twelve lags are used as instruments corresponding to a set of 46 over-identifying restrictions.

for appreciating pressure is much lower than depreciating pressure. Such a policy response in an era of continuous net capital inflows, especially the last decade, accounts for the large build-up in foreign exchange reserves that we have witnessed in the recent past.

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<b>Table 1: Estimates for the benchmark model</b>				
	Coefficient	Std. Error	t-Statistic	p-value
$\alpha_0$	0.212***	0.026	8.247	0
$\alpha_1$	-0.132	0.181	-0.727	0.46
$\alpha_2$	-0.877***	0.066	-4.133	0
Over identifying restriction test: J-statistics = 22.27, p-value = 0.99				
<i>*, ** and *** denotes significance at 10%, 5% and 1% level of significance</i>				

<b>Table 2: Restricted or Linear Model (Eq. 7)</b>				
	Coefficient	Std. Error	t-Statistic	p-value
$c$	0.190***	0.019	9.952	0
$\beta$	-0.192*	0.111	-1.725	0.08
Over identifying restriction test: J-statistics = 24.058, p-value = 0.995				
<i>*, ** and *** denotes significance at 10%, 5% and 1% level of significance</i>				

Table 3: Unrestricted or non-linear model (Eq. 8)				
	Coefficient	Std. Error	t-Statistic	p-value
$c$	0.202***	0.018	11.004	0
$\beta^{OZ}$	-0.479***	0.112	-4.280	0
$\beta^{IZ}$	-0.167	0.154	-1.085	0.278
Over identifying restriction test: J-statistics = 26.499, p-value=0.99 LR statistics ( $H_0: \beta^{OZ} = \beta^{IZ}$ ) = 2.44				
*, ** and *** denotes significance at 10%, 5% and 1% level of significance				

**Figure 1: Zone quadratic versus quadratic preferences**

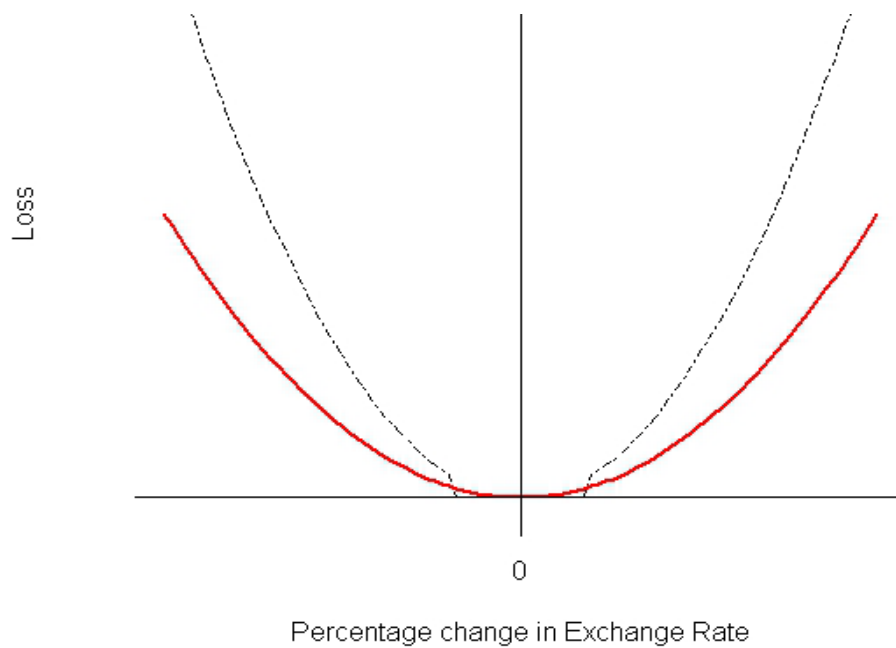


Figure 2: Intervention reaction function for the zone-quadratic model

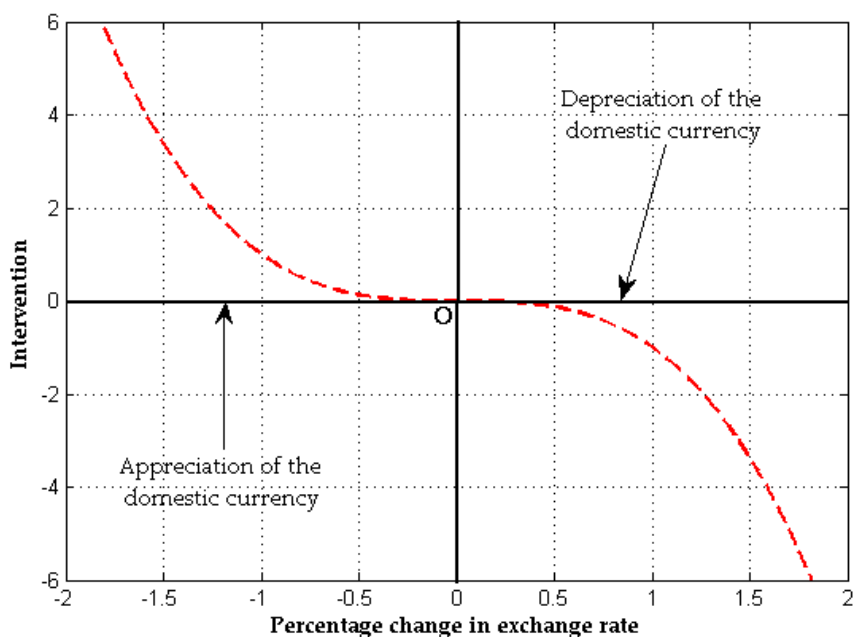


Figure 3: Policy response within and outside the zone of inaction (Actual estimates)

