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INTERVENTION AND INTERNATIONAL  
RESERVE ACCUMULATION IN INDIA**

**Naveen Srinivasan  
Vidya Mahambare  
M. Ramachandran**



**MADRAS SCHOOL OF ECONOMICS  
Gandhi Mandapam Road  
Chennai 600 025  
India**

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**Naveen Srinivasan**

Professor, Madras School of Economics  
[naveen@mse.ac.in](mailto:naveen@mse.ac.in)

**Vidya Mahambare**

Great Lakes Institute of Management, Chennai

**and**

**M. Ramachandran**

Professor, Department of Economics, Pondicherry University

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Gandhi Mandapam Road  
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India**

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**Phone: 2230 0304/2230 0307/2235 2157**

**Fax : 2235 4847/2235 2155**

**Email : [info@mse.ac.in](mailto:info@mse.ac.in)**

**Price : Rs. 35**

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# Capital Controls, Exchange Market Intervention and International Reserve Accumulation in India

Naveen Srinivasan, Vidya Mahambare and M. Ramachandran

## Abstract

*The build up of international reserves by many Asian countries over the last decade or so has attracted widespread interest and debate. This paper seeks to make a contribution to this discussion from the point of view of India. The empirical results are designed to identify the extent to which the accumulation of reserves in India has been driven by two motives which are commonly identified with respect to the recent accumulation of reserves by the Asian EMEs, namely a demand to have insurance against external shocks and a demand to have a high level of export competitiveness, so as to have export-led growth. Our results provide evidence in support of both the motives in explaining India's international reserves accumulation strategy, although, their relative importance does seem to vary overtime depending on external factors. This in turn offers some helpful insights into the causes and likely future path of the global imbalances.*

**Keywords:** Reserve accretion; Capital controls; Exports competitiveness

**JEL Codes:** E58; F31; F32

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## INTRODUCTION

Among the key imbalances that afflict the global economy at present are the burgeoning U.S. current account deficit and the rapid stockpiling of international reserves by emerging market economies (EMEs). According to the Bank for International Settlements (2006), of the roughly \$2.2 trillion increase in global reserves from the end of 2000 to the end of 2005, \$1.5 trillion or around 68% of the increase in global reserve reflects purchases by the EMEs with emerging Asia accounting for much of the increase.<sup>1</sup>

What motivates this unprecedented accumulation of reserves? One line of reasoning is that reserve accretion reflects the desire of EMEs to “self insure” against plausible financial crises, rather than rely on institutions such as the IMF for emergency assistance (Feldstein, 1999).<sup>2</sup> The financial crises of the late 1990s gave developing country policymakers a renewed appreciation for the value of reserves as protection against such crises often caused by abrupt reversals of capital flows. In response, developing countries resorted to impose controls on cross-border capital flows. The control measures were largely designed to encourage capital inflows and discourage outflows.<sup>3</sup> The idea is that these measures will help slow down the drainage of international reserves, giving the authorities ample time to implement corrective policies and to fend off speculators.

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<sup>1</sup> It has been argued in various quarters that the massive purchases of U.S. Treasury bonds by the central banks of emerging countries have enabled the U.S. to finance its current account deficit. Any disruption to this flow could trigger an abrupt depreciation of the U.S. dollar and a sharp rise in U.S. interest rates with adverse consequences for global growth and financial stability. Therefore, the motive behind the unprecedented accumulation of reserves by the EMEs is of considerable importance for international policy agenda.

<sup>2</sup> Aizenman and Marion (2002, 2004) and Aizenman and Lee (2005) provide empirical support for this view.

<sup>3</sup> The case for such an asymmetric administrative controls over capital flows stems from a wide range of justifications: preventing abrupt reversal of capital flows; insulating domestic financial system from external shocks; limiting variability in the exchange rate; and maintaining a specific level/range for the exchange rate. These preventive controls can take a number of forms, including taxes on funds remitted abroad, dual exchange rate, and outright prohibition of funds’ transfers (see Edwards, 1999).

Nevertheless, traditional indicators for “reserve adequacy” indicate that the stock of international reserves is substantially in excess of any conceivable prudential requirements in a number of EMEs, notably in Asia (see Summers, 2006). This suggests that other factors might also be at work driving the rapid accumulation of foreign reserves. It is important to note that reserves increased significantly in economies with limited exchange rate flexibility. Therefore, a plausible explanation stems from the policymakers’ desire to prevent undue appreciation of their currencies and maintain export competitiveness (Dooley et al., 2003 and Ramachandran and Srinivasan, 2007). Such asymmetric policy intervention, which aims at strengthening export competitiveness, can also contribute to reserve accretion.

This paper seeks to quantify the relative importance of these alternative views in explaining India’s international reserves accumulation strategy. Like many other EMEs, India’s decision to liberalize its intricately planned economy in 1991 was necessitated by a balance-of-payment crisis. The crisis indicated the urgent need to build up adequate amount of reserves as insurance. In order to accomplish this, several administrative controls were put in place to discourage capital outflows and encourage inflows (Nayyar, 2000).<sup>4</sup> Additionally, like in majority of EMEs reserves were accumulated in the context of foreign exchange intervention intended to promote export-led growth by preventing exchange rate appreciation (see Calvo and Reinhart, 2002).<sup>5</sup>

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<sup>4</sup> As Governor Reddy (2000) notes, the management of India’s integration into the world financial market has been based, until very recently, on fundamental asymmetries between residents and non-residents, and between corporates and individuals. Resident corporates have had to obtain approval of various sorts before exporting capital, and resident individuals were, virtually prohibited from holding financial assets in foreign currency.

<sup>5</sup> Nevertheless, there is wide diversity among the Asian economies in terms of saving and investment rates, fiscal deficit, drivers of growth (domestic versus external) and the degree of flexibility in their exchange rates. Also, unlike many other Asian economies capital flows as opposed to current account surpluses, played an increasingly important role in the accumulation of reserves in India. Therefore the motives behind reserve accretion can only be understood in conjunction with other features typifying the country under examination.

To anticipate our findings, our empirical results provide evidence in support of both the motives identified in the literature, although, their relative importance does seem to vary overtime depending on external factors. This in turn explains why the pace of reserve accretion varies overtime and offers some helpful insights into the causes and likely future path of the global imbalances. The rest of the paper is organized as follows. Section 2 sets up the model, introduces both the motives identified in the literature for reserve accretion and derives the implied reserve demand function as the first-order condition of an optimal control problem. The identification method and the hypothesis testing strategy for the presence of such motives are described. Section 3 presents and discusses our empirical results. Section 4 concludes.

## THE THEORETICAL FRAMEWORK

As is customary in the monetary policy literature, the central bank is assumed to minimize an intertemporal loss function. Our focus here is specifically on reaction functions designed to examine exchange rate management. Thus, intervention ( $INV_t$ ) can be thought of as our policy instrument.<sup>6</sup> An important aspect of monetary policy making is that policy actions are taken at the end of time period  $t-1$ ,  $INV_t \in \Omega_{t-1}$ , where  $\Omega_{t-1}$  denotes the information available to the monetary authorities and market participants. Hence, the central banker here has no informational advantage over the public since neither of them observe at time  $t-1$  the realization of the disturbances at time  $t$ . Because there is no private information, the central banker's information set coincides with the

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<sup>6</sup> The traditional approach to the estimation of intervention reaction function has often been criticized because of the *ad hoc* specification typically employed by this literature (see Sarno and Taylor, 2001). Almekinders and Eijffinger (1996) proposed a theoretical model in which they obtain an intervention reaction function by combining the exchange rate model with a particular loss function for the central bank. A similar strategy is employed here.

public's and is also given by  $\Omega_{t-1}$ . This timing device is captured by the following intertemporal criterion:

$$\text{Min}_{\{INV_{t+\tau}\}_{\tau=0}^{\infty}} E_{t-1} \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau},$$

where  $0 < \delta < 1$  is the discount factor and  $INV_t$  is the volume of intervention defined as purchases of foreign currency by the domestic central bank.

We capture the export competitiveness motive for reserve accretion by assuming that the central bank cares about real exchange rate stabilization i.e., is penalized for deviation of  $\tilde{Q}_t$  (% change in the real exchange rate) around equilibrium ( $\tilde{Q}^*$ ).<sup>7</sup> Thus, the period loss function  $L_t$  is specified as:

$$L_t = \frac{1}{2} (INV_t - INV_t^T)^2 + \frac{\lambda}{2} \left\{ (\tilde{Q}_t - \tilde{Q}^*)^2 + \frac{\gamma}{3} (\tilde{Q}_t - \tilde{Q}^*)^3 \right\}, \quad (1)$$

where  $\lambda > 0$  is the relative weight on exchange rate stabilization,  $INV_t^T$  is a time-varying interim target for intervention, and ' $\gamma$ ' is the asymmetric preference parameter.

Note that when  $\gamma \neq 0$ , our model exhibits preference asymmetry with respect to exchange rate stabilization. That is, policymakers are

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<sup>7</sup> Here  $Q_t = \frac{S_t P_t^f}{P_t^d}$ , where  $S_t$  is the nominal exchange rate (a rise is depreciation of the

domestic currency) and  $P_t^f$  and  $P_t^d$  are foreign and domestic price level respectively. For simplicity, we shall assume that the equilibrium real exchange rate is a constant, that is, purchasing power parity (PPP) condition holds. Thus,  $\tilde{Q}^* = 0$  in what follows.

allowed to treat differently the rate of appreciating and depreciating pressure on the real exchange rate. This is designed to capture the policymakers' interest in preserving export competitiveness. In the plausible case where,  $\gamma < 0$ , the authority's response to appreciating pressure is more forceful than to depreciating pressure of the same magnitude. To see this note that,  $\partial L_t / \partial \tilde{Q}_t = \lambda \left[ \tilde{Q}_t + \frac{\gamma}{2} (\tilde{Q}_t)^2 \right] < 0$ , that is, policymakers' loss increases at the margin with the rate of real exchange rate appreciation ( $\tilde{Q}_t < 0$ ). Also note that,  $\partial^2 L_t / \partial (\tilde{Q}_t)^2 = \lambda(1 + \gamma(\tilde{Q}_t)) > 0$ , so that loss is increasing with the magnitude of the goal variable. Thus, under asymmetric preferences both the sign and the magnitude of deviation of the goal variable are relevant to the policymaker. The cubic form also nests the usual quadratic specification as a special case (see Surico, 2003 for more details).

In addition, a crucial feature of our model is that the interim target for intervention  $INV_t^T$  is assumed to respond to changes in foreign interest rates. In fact, a variety of empirical studies have pointed out the importance of external influences for capital flows and as a consequence for intervention activity. For instance, Calvo et al., (1993, 1996), Chohan et al., (1998), Montiel and Reinhart (1999) and Kim (2000) report that a large portion of capital inflows into both Asia and Latin America are induced by 'good news'- the reduction in the foreign interest rate.<sup>8</sup> Following the literature we assume that capital flows (and as a consequence intervention) are determined by change in foreign

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<sup>8</sup> Although, domestic factors remain important, it only partially explains capital flows. As Calvo (1996) notes, lower interest rates in the developed nations attracted investors to the high-investment yield and improving economic prospects of economies in Asia and Latin America. This turn of events was heralded as good news in most developing countries. Moreover, the relative importance of external shocks seems a robust feature of capital flows.

interest rate; hence, a negative change implies good news (inflows) and a positive change implies bad news (outflows) for India. That is,

$$INV_t^T = k \left( \frac{e^{-\alpha(\hat{R}_{t-1}^F)} - 1}{\alpha} \right), \quad 0 \leq k \leq 1 \quad (2)$$

where  $\alpha > 0$  is the asymmetric response parameter and ' $\hat{R}_{t-1}^F$ ' denotes change in foreign interest rate at the end of time period  $t-1$ . We assume that  $\hat{R}_{t-1}^F$  is exogenous (given that India is a small open economy) and is normally distributed with constant mean  $\bar{R}^F$  and variance  $\sigma_{\hat{R}^F}^2$ . Specifically, a positive change in foreign interest rates (bad news) results in outflow of capital. As a consequence there is pressure on the domestic currency to depreciate. The RBI's objective is to curb exchange rate volatility.<sup>9</sup> In response the central bank sells dollars,  $INV_t^T < 0$ . In contrast, when the change in foreign interest rate is negative, there is inflow of capital and pressure on the domestic currency to appreciate. The central bank in response buys dollars,  $INV_t^T > 0$ .

Moreover, note that the interim target for intervention responds asymmetrically to changes in foreign interest rates. This is done to reflect the constraints on capital outflows prevalent in India [and so the] insurance motive.<sup>10</sup> That is, when  $\gamma = 0$  and  $\alpha > 0$  preferences are symmetric with respect to real exchange rate stabilization, but there are

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<sup>9</sup> As Governor Reddy (1997) states, "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 rate fluctuations becomes passive i.e., one of preventing undue appreciation in the context of large inflows and providing supply of dollars in the market to prevent sharp depreciations".

<sup>10</sup> At the outset we acknowledge that intervention of this kind is only one way of understanding the insurance motive in emerging markets. The purpose of reserves in these countries is not just for defense against short run stochastic disturbances of the kind analyzed here. Reserves are also demanded as defense in the face of long-run structural changes in trade patterns, which will influence a country's competitiveness.

constraints on capital outflows. To see this Figure 1 plots Eq. (2) for  $\alpha = k = 0.5$ . The  $x$ -axis plots both positive (outflow) and negative (inflow) change in foreign interest rates while the  $y$ -axis plots the implied behaviour of  $INV_t^T$ . As we can see the interim target for intervention responds nonlinearly to  $\hat{R}_{t-1}^F$ .

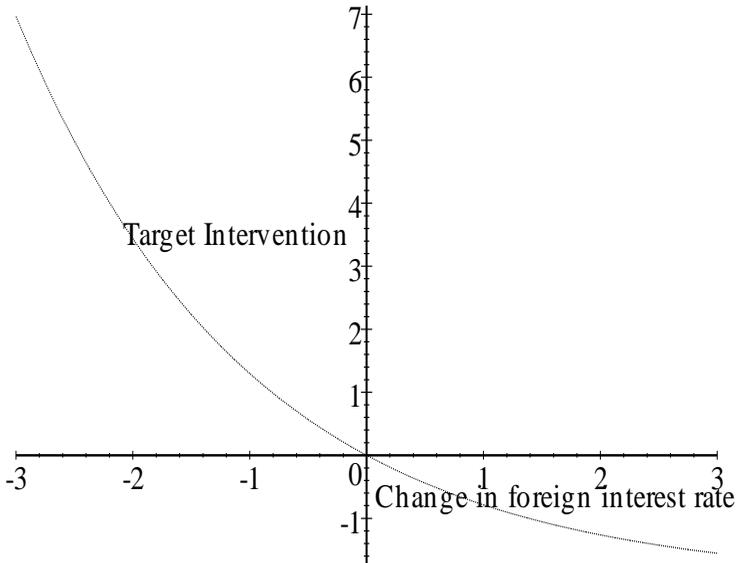
Specifically, when there is a negative change in foreign interest rates (inflow of capital), there is pressure on the real (nominal) exchange rate to appreciate.<sup>11</sup> The central bank wants to smoothen volatility i.e., it wants to curb the rate of exchange rate appreciation. To accomplish this, the central bank intervenes in the foreign exchange market and buys dollars i.e.,  $INV_t^T \succ 0$ . In contrast, when there is a positive change in foreign interest rate the response of  $INV_t^T$  is much less pronounced for the same magnitude shock. This is because capital controls (restrictions on capital outflows) prevent the actual real (nominal) exchange rate from depreciating by much in the first place. Indeed, at times of pressure on outflows, the RBI has resorted to both monetary and administrative measures to contain the pressure. These restrictions in turn prevent the rupee from depreciating by the same magnitude. Hence intervention (selling dollars in this case,  $INV_t^T \prec 0$ ) activity is much less pronounced for the same magnitude shock. Thus, the framework allows us to mimic intervention behavior in the presence of capital controls without explicitly incorporating this feature into the model.<sup>12</sup>

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<sup>11</sup> This is because in the short run, if the prices of goods and services are slow to change, nominal exchange rate movements will be reflected immediately in real exchange rate changes. Thus, implicitly we appeal to short-run price rigidity.

<sup>12</sup> Moreover, the functional form employed for  $INV_t^T$  also nests the standard linear response to changes in foreign interest rates as a special case. In the limiting case it can be shown that as  $\alpha \rightarrow 0$ , the interim target for intervention responds linearly to changes in foreign interest rates.

**Figure 1: Plot of  $INV_t^T$  in Response to  $\hat{R}_{t-1}^F$**



Finally, since the paper focuses on the motives behind central bank intervention, we posit a linear relationship between the policy instrument and the real exchange rate. Specifically, it is assumed that interventions can dampen the rate of exchange rate depreciation/appreciation i.e., smooth exchange rate volatility.<sup>13</sup> That is,

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<sup>13</sup> Whether or not official intervention is effective in influencing exchange rates is an issue of crucial policy importance, and have been subject of a vast academic literature (see Edison, 1993 for a survey). These issues are beyond the scope of this paper.

$$\tilde{Q}_t = a_0 + a_1 INV_t + a_2 \left( \frac{e^{-\alpha(\hat{R}_{t-1}^F)} - 1}{\alpha} \right) + \varepsilon_t, \quad (3)$$

where  $a_1 > 0$ ,  $a_2 < 0$  and  $\varepsilon$  the disturbance term is an i.i.d. shock with zero mean and variance  $\sigma_\varepsilon^2$ . Also note that the response of  $\tilde{Q}_t$  to changes in foreign interest rates is asymmetric owing to restrictions on capital outflows. The disturbance term is introduced to acknowledge the fact that policymakers have imperfect control over the exchange rate.

In this framework, the central bank's optimization problem involves minimizing (1) by choosing policy instrument  $INV_t$  subject to (2) and (3) which leads to the following first-order condition:

$$0 = (INV_t - INV_t^T) + \frac{\lambda a_1}{2} E_{t-1} \left( 2(\tilde{Q}_t) + \gamma(\tilde{Q}_t)^2 \right)$$

or

$$INV_t = -\lambda a_1 E_{t-1}(\tilde{Q}_t) - \frac{\lambda \gamma a_1}{2} E_{t-1}(\tilde{Q}_t)^2 + \frac{k}{\alpha} \left( e^{-\alpha(\hat{R}_{t-1}^F)} - 1 \right), \quad (4)$$

where we have substituted out for  $INV_t^T$ . Here (4) is the optimal intervention response to the developments in the economy. Our task consists in estimating this nonlinear feedback rule in order to evaluate whether the asymmetric preference parameter  $\gamma$  and the asymmetric response parameter  $\alpha$  are significantly different from zero. In order to simplify things we linearize the exponential term in (4) by means of a second-order Taylor series expansion around  $\alpha = 0$  which yields,

$$e^{-\alpha(\hat{R}_{t-1}^F)} \cong 1 - \alpha(\hat{R}_{t-1}^F) + \frac{\alpha^2(\hat{R}_{t-1}^F)^2}{2}. \text{ Substituting this approximation in}$$

(4) yields our intervention reaction function:

$$INV_t = \beta_1 E_{t-1}(\tilde{Q}_t) + \beta_2 (\hat{R}_{t-1}^F) + \beta_3 E_{t-1}(\tilde{Q}_t)^2 + \beta_4 (\hat{R}_{t-1}^F)^2 + w_t, \quad (5)$$

where  $\beta_1 = -\lambda a_1 < 0$ ,  $\beta_2 = -k < 0$ ,  $\beta_3 = -\left(\frac{\lambda a_1 \gamma}{2}\right) \neq 0$ ,

$\beta_4 = \left(\frac{k\alpha}{2}\right) \neq 0$  and  $w_t$  denotes the approximation error.

Finally, taking unconditional expectations of (5), and using the fact that  $E(\tilde{Q}_t) = 0$ , we obtain:

$$E(INV_t) = \beta_5 - \left(\frac{\lambda a_1 \gamma}{2}\right) \sigma_{\tilde{Q}}^2 + \left(\frac{k\alpha}{2}\right) \sigma_{\hat{R}^F}^2, \quad (6)$$

where  $\beta_5 = -k(\bar{R}^F)$ . Note that on average intervention activity depends on how successful intervention is, the preferences of the central bank and the volatility of  $\tilde{Q}$  and  $\hat{R}^F$ . Thus, for example in the case of asymmetric preferences if the policymaker is averse to the rate of domestic currency appreciation ( $\gamma < 0$ ), then intervention is positive i.e., the central bank buys dollars. Intuitively, greater the volatility of the real exchange rate, greater is the probability of real exchange rate appreciation (and depreciation). If the central bank is more concerned about the rate of appreciation ( $\gamma < 0$ , export competitiveness motive), then planned intervention will be positive on average.

Similarly, in the case of capital controls, if  $\alpha > 0$ , then intervention is positive on average. Intuitively, greater the volatility of  $\hat{R}^F$ , higher the probability of inflow (and outflow) of capital. Because capital controls (insurance motive) imposes restrictions on outflows in the model, appreciating pressure on the domestic currency tends to dominate. The central bank's objective is to curb the rate of appreciation.

To do this it has to intervene in the foreign exchange market and buy dollars i.e., planned intervention will be positive on average. Thus, the model is capable of accounting for intervention behaviour overtime depending on the signs of the parameters,  $\gamma$  and  $\alpha$ .

## Identification

Note that, the coefficients  $\beta_3$  and  $\beta_4$  enter our intervention reaction function (5) if and only if  $\gamma \neq 0$  and  $\alpha \neq 0$ . Accordingly, the optimal policy rule is nonlinear (in variables and not in parameters) if and only if the preferences of the central bank are asymmetric with respect to exchange rate stabilization and there are constraints on capital flows. Thus, from the viewpoint of the foregoing analysis the coefficient  $\beta_3$  and  $\beta_4$  embodies the information about both preference asymmetry and constraints on capital flows, so that the restriction  $\gamma = \alpha = 0$  implies  $\beta_3 = \beta_4 = 0$ . Hence testing  $H_0: \beta_3 = \beta_4 = 0$  is equivalent to testing  $H_0: \gamma = \alpha = 0$ . Thus, if  $\beta_3 > 0$  ( $\beta_4 > 0$ ) then  $\gamma < 0$  ( $\alpha > 0$ ) since all other model parameters are positive. Thus, the model is designed to identify the extent to which intervention activity in India has been driven by the two motives commonly identified in the literature to explain the recent accumulation of reserves by the Asian EMEs.

Nevertheless, the model as it stands might be vulnerable to the criticism that the two kinds of non-linearities identified in (5) does not enable one to discriminate the competitiveness motive from the insurance motive. This is because *ex ante*  $E_{t-1}(\tilde{Q}_t)^2$  and  $(\hat{R}_{t-1}^F)^2$  are likely to be strongly correlated. However, we note that the association between these two variables *ex post* is likely to be considerably weaker if intervention is successful in stabilizing exchange rate volatility i.e.,  $\alpha_1 > 0$ . In order to illustrate this we simplify the model. Specifically, in

the limiting case it can be shown that as  $\gamma \rightarrow 0$  and  $\alpha \rightarrow 0$ , equations (3) and (5) become:

$$\tilde{Q}_t = a_0 + a_1 INV_t - a_2 \hat{R}_{t-1}^F + \varepsilon_t, \quad (3.1)$$

and

$$INV_t = \beta_1 E_{t-1}(\tilde{Q}_t) + \beta_2 (\hat{R}_{t-1}^F) + w_t, \quad (5.1)$$

where we have exploited L'Hôpital's rule. Our purpose here is to simply show that intervention dampens the association between these two variables irrespective of whether there is preference asymmetry and /or asymmetric capital controls. Taking conditional expectations of (3.1) based on  $\Omega_{t-1}$  and substituting the resulting expression in (5.1) for

$E_{t-1}(\tilde{Q}_t)$ , yields:

$$INV_t = c_0 + c_1 \hat{R}_{t-1}^F + c_2 w_t, \quad (5.2)$$

where  $c_0 = -\left(\frac{\lambda a_0 a_1}{1 + \lambda(a_1)^2}\right)$ ,  $c_1 = \left(\frac{\lambda a_1 a_2 - k}{1 + \lambda(a_1)^2}\right)$  and  $c_2 = \left(\frac{1}{1 + \lambda(a_1)^2}\right)$ .

Finally, substituting (5.2) in (3.1) for  $INV_t$ , squaring the resulting expression and taking first derivative with respect to  $(\hat{R}_{t-1}^F)^2$  yields;

$$\frac{\partial(\tilde{Q}_t)^2}{\partial(\hat{R}_{t-1}^F)^2} = \frac{a_1(\lambda a_1 a_2 - k)}{(1 + \lambda(a_1)^2)^2} \left[ a_1(\lambda a_1 a_2 - k) - 2a_2(1 + \lambda(a_1)^2) \right] + (a_2)^2 \quad (7)$$

where (7) is the response of  $(\tilde{Q}_t)^2$  to  $(\hat{R}_{t-1}^F)^2$  when the central bank intervenes ( $a_1 > 0$ ) to stabilize exchange rate volatility. In contrast, when there is no intervention ( $a_1 = 0$ ), the above expression simplifies

to,  $(a_2)^2$ . Note that the first term in (7) is negative. Thus, the key point to highlight is that the response of  $(\tilde{Q}_t)^2$  to  $(\hat{R}_{t-1}^F)^2$  is weaker when the central bank intervenes. Hence, intervention at least manages to considerably weaken (if not completely destroy) the ex post association between these two variables.

## **EMPIRICAL RESULTS AND DISCUSSION**

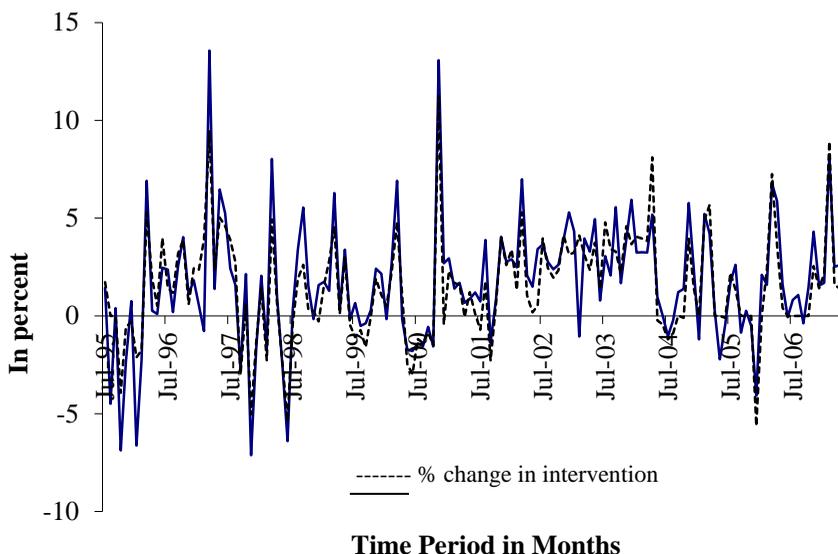
### **Data**

For India intervention data is not available at high frequency. Recent empirical literature on the effectiveness of central bank intervention uses daily data. Ideally, one should use minute-by-minute data, since this is the time scale on which intervention of monetary authorities in the foreign exchange market occurs (Sarno and Taylor, 2001). But for India intervention data is only available at monthly frequency. Nevertheless, data on foreign currency assets is available at weekly frequency. So we proxy intervention by changes in foreign currency assets.<sup>14</sup> In practice we use the weekly % change in foreign currency assets ( $\tilde{R}_t$ ) to avoid scaling problem. This proxy may not amount to significant error in measurement of the variable in the Indian context as the plot of percentage change in monthly purchase/sale of foreign exchange (intervention activity) by the RBI and percentage change in foreign currency assets (see Figure 2) during the period July 1995 to April 2007 has a correlation coefficient of 0.887.

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<sup>14</sup> We acknowledge that changes in foreign currency assets represent a crude proxy for intervention activity since reserves may change for a number of reasons and often are not related to official intervention. Reserves increase, for example, with valuation changes on existing reserves. Our results are subject to this data limitation.

**Figure 2: Percentage Change in Cumulative Intervention and Foreign Currency Assets**



We also note that at weekly frequency real exchange rate data is not available. Unfortunately, exactly what moves the nominal and real exchange rates day to day, let alone month to month, is difficult to determine. In the short run, nominal exchange rates depend primarily on financial market variables and expectations; and, if the prices of goods and services are slow to change (as assumed), nominal exchange rate movements will be reflected immediately in real exchange rate changes. Hence we use nominal exchange rate as a proxy for real exchange rate. Moreover, monitoring of the nominal rate, as opposed to the real exchange rate, has also been official RBI policy. As the former RBI governor Jalan (1999) argues, *"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'.*

Thus, our empirical analysis uses weekly data for the sample period 11<sup>th</sup> November 1994 to 22<sup>nd</sup> September 2006. The sample is chosen to cover the market based exchange rate system. Although, the market based exchange rate system was introduced in March 1993 the exchange rate was fixed at Rs 31.37 per US\$ until 11<sup>th</sup> November 1994. The present exchange rate system, in principle, seeks to determine the exchange rate through forces of supply and demand in the market. However, in practice it is a managed float with the central bank playing the role of a big broker in terms of management. The variables  $\tilde{S}_t$  is measured as  $(\Delta \log S_t) * 100$  and  $\tilde{R}_t$  is measured as  $(\Delta \log R_t) * 100$  with  $S_t$  and  $R_t$  being rupee price per US\$ and foreign currency assets respectively. We do not consider other components of reserve assets such as gold, SDR and Tranch position with IMF as they constitute a very negligible proportion of total reserves and are not used for intervention purposes. Finally,  $\hat{R}_{t-1}^F$  is measured as the weekly change in the 3-month U.S. Treasury bill rate. The standard unit root tests indicate (not reported here) that these variables are all stationary process.

### **Empirical model**

We now proceed to empirically evaluate our model. To do this, we use (5) and prior to estimation we replace expected values with actual values. Thus, we use ex post data to estimate the model. Our benchmark reserve demand equation is given by:

$$\tilde{R}_t = \beta_0 + \beta_1(\tilde{S}_t) + \beta_2(\hat{R}_{t-1}^F) + \beta_3(\tilde{S}_t)^2 + \beta_4(\hat{R}_{t-1}^F)^2 + v_t, \quad (8)$$

where  $\beta_0$  is a constant intercept term,  $\tilde{S}_t$  is the percentage change in the nominal exchange rate and

$v_t = -\left\{ \beta_1 \left( \tilde{S}_t - E_{t-1} \left( \tilde{S}_t \right) \right) + \beta_3 \left( \tilde{S}_t^2 - E_{t-1} \left( \tilde{S}_t \right)^2 \right) \right\}$  is a linear combination of forecast errors and therefore is orthogonal to any variable in the information set available at time  $t-1$ .

As is conventional in models involving rational expectations, the estimation method relies upon the choice of a set of instruments,  $Z_t$ , that help forecast the explanatory variables but are uncorrelated with the errors. We shall refer to this forecast as the *ex post* or model generated forecast, since it is the fitted values of the realized nominal exchange rate series. Then, the GMM (Hansen, 1982) can be used to estimate the parameter vector  $\beta_i$ 's by exploiting the set of orthogonality conditions. In practice, we employ a 12-lag Newey-West estimator of the covariance matrix. Hansen's J test is used to test the over-identification restrictions.

**Table 1: Estimates of the Reserve Demand Model**

<b>Variables</b>	<b>Coefficients (<math>\rho</math>-values)</b>	<b>Coefficients (<math>\rho</math>-values)</b>
constant	0.666 (0.00)	0.071 (0.05)
$\tilde{S}_t$	-0.673 (0.00)	-0.593 (0.00)
$\hat{R}_{t-1}^F$	0.513 (0.80)	-4.904 (0.00)
$\tilde{S}_t^2$	-1.102 (0.00)	-0.072 (0.00)
$(\hat{R}_{t-1}^F)^2$	-0.117 (0.61)	0.285 (0.00)
$D1\tilde{S}_t^2$		1.422 (0.00)
$D1(\hat{R}_{t-1}^F)^2$		0.956 (0.00)
$D2\tilde{S}_t^2$		0.374 (0.00)
$D2(\hat{R}_{t-1}^F)^2$		-0.061 (0.63)
$D1$		0.512 (0.00)
$D2$		0.321 (0.00)
	$J \{53\} = 35.98 (0.96)$	$J \{95\} = 34.15 (0.99)$

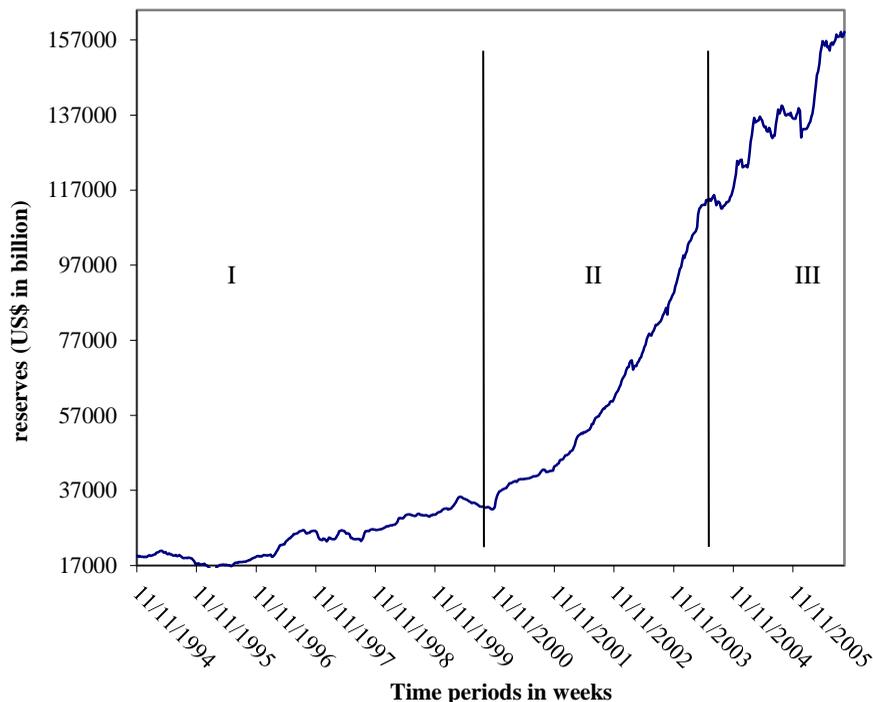
**Notes:**  $D1 = 1$  from 10<sup>th</sup> November 2000 to 23<sup>rd</sup> April 2004 and zero otherwise.  $D2 = 1$  from 30<sup>th</sup> April 2004 to 22<sup>nd</sup> September 2006. Up to twelve lags of  $\tilde{R}_t$ ,  $\tilde{S}_t$ ,  $\hat{R}_{t-1}^F$ ,  $\tilde{S}_t^2$ ,  $(\hat{R}_{t-1}^F)^2$  are used as instruments in the GMM estimation of the benchmark model and up to twelve lags of  $\tilde{R}_t$ ,  $\tilde{S}_t$ ,  $\hat{R}_{t-1}^F$ ,  $\tilde{S}_t^2$ ,  $(\hat{R}_{t-1}^F)^2$ ,  $D1\tilde{S}_t^2$ ,  $D1(\hat{R}_{t-1}^F)^2$ ,  $D2\tilde{S}_t^2$ ,  $D2(\hat{R}_{t-1}^F)^2$  and two additive ( $D1$  and  $D2$ ) dummies are used as instruments in the estimation of augmented model. The J-statistics indicate that the overidentifying restrictions corresponding to both models are satisfied.

The estimates of the benchmark reserve demand equation are presented in the first column of Table 1. Twelve lags of  $\tilde{R}_t$ ,  $\tilde{S}_t$ ,  $\tilde{S}_t^2$ , and eleven lags of  $\hat{R}_{t-1}^F$  and  $(\hat{R}_{t-1}^F)^2$  are used as instruments; hence, we

have 58 instruments to estimate 5 parameters that result in 53 overidentifying restrictions. The J-test that follows the  $\chi^2$  distribution with degrees of freedom equal to number of overidentifying restrictions is used to test the null hypothesis that overidentifying restrictions are satisfied. The estimated statistic (35.98) with a  $p$ -value 0.96 implies that the null cannot be rejected.

The coefficient estimates show that the constant, percentage change in exchange rate, and square of percentage change in exchange rate, are all statistically significant while  $\hat{R}_{t-1}^F$  and  $(\hat{R}_{t-1}^F)^2$  are not. The negative coefficient on  $\tilde{S}_t$  implies that exchange rate intervention is leaning against wind. However, the coefficient on  $\tilde{S}_t^2$  comes with the wrong sign, implying that the authority's response to domestic currency depreciation is more forceful than to appreciating pressure of the same magnitude. But according to our model (see (6) above) if the central bank is averse to the rate of domestic currency depreciation ( $\gamma > 0$ ), then planned intervention will be negative on average. In other words, there should be a deceleration of reserves over the sample period. This is however, inconsistent with the data on reserves (see Figure 3). Thus, the evidence derived from our benchmark model is not appealing as it fails to explain reserve accretion during the sample period.

**Figure 3: The Accretion of Reserves in India**



A plausible explanation for this result is that our benchmark model is mis-specified. For example, a structural break during the sample period which is not accounted for, may affect one or all the parameters of the model. Over the entire sample period, there is no doubt that many important developments occurred that had a significant bearing on reserve growth.<sup>15</sup> Indeed, Figure 3 suggests three different regimes based on the rate of reserve accretion during the sample period. The first

<sup>15</sup> The idea that there have been structural breaks in the demand for international reserves for some countries in emerging Asia is confirmed by Aizenman et al. (2004). Using data for Korea, they find evidence of a break in the pattern of hoarding of international reserves in the post-1997 period. Moreover, the authors argue that the self-insurance motive became stronger following the crisis.

phase covers the week beginning from 11<sup>th</sup> November 1994 to 3<sup>rd</sup> November 2000 during which US\$ 15.802 billion was accumulated – a period of relatively low reserve growth; the second phase covers the week from 10<sup>th</sup> November 2000 to 23<sup>rd</sup> April 2004 during which US\$ 82.466 billion was accumulated – a phase of rapid reserve accumulation; and the third phase covers the period from 30<sup>th</sup> April 2004 to 22<sup>nd</sup> September 2006 during which US\$ 48.603 billion was accumulated – a phase where reserve growth moderated compared to the second phase (consolidation phase). Each period may signify a shift in policy as the underlying motive(s) behind reserve accumulation underwent a change.

To take into account this shift in policy, the benchmark model is augmented by incorporating multiplicative and additive dummies. The augmented model is:

$$\begin{aligned} \tilde{R}_t = & \beta_0 + \beta_1 \tilde{S}_t + \beta_2 \hat{R}_{t-1}^F + \beta_3 \tilde{S}_t^2 + \beta_4 (\hat{R}_{t-1}^F)^2 + \beta_5 D1 \tilde{S}_t^2 + \beta_6 D1 (\hat{R}_{t-1}^F)^2 \\ & + \beta_7 D2 \tilde{S}_t^2 + \beta_8 D2 (\hat{R}_{t-1}^F)^2 + \beta_9 D1 + \beta_{10} D2 + v_{1t} \end{aligned} \quad (9)$$

where  $D1 = 1$  from 10<sup>th</sup> November 2000 to 23<sup>rd</sup> April 2004 and zero otherwise.

$D2 = 1$  from 30<sup>th</sup> April 2004 to 22<sup>nd</sup> September 2006 and zero otherwise.

The GMM estimates of the augmented reserve demand specification (9) are obtained by using up to twelve lags of  $\tilde{R}_t$ ,  $\tilde{S}_t$ ,  $\hat{R}_{t-1}^F$ ,  $\tilde{S}_t^2$ ,  $(\hat{R}_{t-1}^F)^2$ ,  $D1 \tilde{S}_t^2$ ,  $D1 (\hat{R}_{t-1}^F)^2$ ,  $D2 \tilde{S}_t^2$ ,  $D2 (\hat{R}_{t-1}^F)^2$  and two additive dummies ( $D1$  and  $D2$ ) as instruments. We have 106 instruments to estimate 11 coefficients; hence, there are 95 overidentifying restrictions. The estimates of the augmented model are presented in the second column of Table 1. The estimated  $\chi^2$  statistic is 34.15 with a  $p$ -value 0.99;

implying that the overidentifying restrictions are satisfied. The estimated coefficients on  $\tilde{S}_t$  and  $\hat{R}_{t-1}^F$  corresponding to the first phase ( $D1 = D2 = 0$ ) are negative and statistically significant; indicating that the intervention is aimed at stabilizing the exchange rate and a negative (positive) change in U.S. Treasury bill rate has a positive (negative) impact on reserves.

However, the coefficient embodying preference asymmetry (export competitiveness motive) is negative [-0.072 (0.00)] and statistically significant; implying that the policymakers were more worried about rupee depreciation than rupee appreciation. In this regard we note that this was the period during which the Asian financial crisis hit and there was genuine fear of capital flight and pressure on the rupee to depreciate, similar to many other Asian currencies. As Nayyar (2002) points out the second half of 1997-98 witnessed a mounting pressure on the rupee, since there was an expectation of capital outflows arising from contagion effects as the financial crisis spread through several countries in Asia. The problem was exacerbated by a sharp slow down in capital inflows into India as confidence in international financial markets took a hit. The RBI sought to manage the situation by large sales of US dollars in both the spot and the forward market.

At the same time in response to a genuine fear of capital flight the RBI was forced to put in place several administrative controls to discourage capital outflows and encourage inflows. This suggests that intervention response to a positive change in U.S. interest rate (which leads to capital outflow) should have been much less forceful than response to a negative change in U.S. interest rate (which leads to capital inflow) during this period. Our results support this as the coefficient embodying insurance motive  $\beta_4$  is positive [0.285 (0.00)] and statistically significant. Thus, there were two opposing forces at work in the first phase – asymmetric response to changes in U.S. interest rates

because of capital controls leading to reserve accretion while the response to depreciating pressure on the exchange rate eroding it. In sum, conflict between the insurance motive and the competitiveness motive explain why reserve growth was moderate during the first phase.

In contrast during the second phase there was substantial reserve accretion. Some interesting inferences emerge from the results corresponding to the period from 10<sup>th</sup> November 2000 to 23<sup>rd</sup> April 2004 ( $D1 = 1$ ;  $D2 = 0$ ). The coefficient embodying preference asymmetry is given by  $(\beta_3 + \beta_5)$  and the coefficient embodying insurance motive is given by  $(\beta_4 + \beta_6)$ . During this phase the coefficient on exchange rate square is positive [1.35 (0.00)] and highly significant; indicating that the central bank was in favour of rupee depreciation. Similarly, the coefficient capturing insurance motive  $(\beta_4 + \beta_6)$  is positive [1.241 (0.00)] and statistically significant. Moreover, the magnitude of this coefficient in the second phase is greater, suggesting that the insurance motive became relatively more important during this phase compared to the first. This is not altogether surprising, since in the aftermath of the Asian crisis in 1997-98, even countries in the region that had escaped the worst effects of the crisis but remained concerned about future crises, notably China, built up reserves (see Bernanke, 2005). Thus, both export competitiveness and insurance motive seems to have contributed to reserve growth during this phase.

During the third phase, the coefficient embodying preference asymmetry  $(\beta_3 + \beta_7)$  is positive [0.302 (0.00)] and significant, but the magnitude of the coefficient is less than that corresponding to the second phase. Also, during this period the coefficient on insurance motive  $\beta_8$  is statistically insignificant implying no change in slope during the third phase. By implication the magnitude of the insurance coefficient

$(\beta_4 + \beta_8)$  is smaller [0.285 (0.00)] in the third phase relative to the second phase [1.241 (0.00)]. This suggests that in the more recent period the insurance motive has increasingly become less important. This is not surprising given that by the end of the second phase itself, the RBI carried ample crisis protection cover as measured by any conventional metric of reserve adequacy. In fact, the RBI itself has noted this on several occasions (see Jalan, 2002). Subsequently, there was a gradual dismantling of controls on capital outflows. In particular restrictions on overseas investment and lending and the prepayment of foreign loans have been gradually relaxed. Thus, the fall in magnitude of response coefficients on both forms of asymmetry during the third phase may reflect the fact that reserves have grown to such an extent that policymakers have started to increasingly view it to be a problem of plenty.

Finally, in order to ascertain the forecasting advantage of our augmented model as opposed to our benchmark model, the models are compared using Diebold and Mariano (1995) predictive accuracy test. The estimated mean absolute errors of the benchmark model and its augmented version are 0.987 and 0.762 respectively. The test statistics for testing the null hypothesis of equal predictive accuracy of these two competing specifications is  $-2.282$  with a  $p$ -value of 0.02. The lower mean absolute error associated with the augmented model and rejection of null of equal predictive accuracy indicates that the augmented version has additional predictive ability.

## **CONCLUSION**

This paper seeks to make a contribution to the discussion on the unprecedented accumulation of international reserves by Asian EMEs in recent years. Specifically, in the Indian context, it explains the emergence of reserves as coming from the policy choices of the central bank itself, about exchange market intervention. The empirical results provide evidence in support of both precautionary and export competitiveness motive in explaining India's international reserves accumulation strategy, although, their relative importance does seem to vary overtime depending on external factors. Crucially, however the pace of reserve accretion in recent years has moderated as policymakers have started to increasingly view it to be a problem of plenty. A similar development has taken place in South Korea, Taiwan, Hong Kong, and Singapore. The increase in their combined reserves in 2005 was about \$24 billion, which was less than a quarter of the level of 2004. This has in turn resulted in a gradual dismantling of restrictions on capital flows and a move towards more flexible exchange rate system. This suggests that the imbalances that plague the global economy at present are on their way to being corrected as the factors that attracted global savings to the U.S. in the first place gradually start to unwind.

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\$ Restricted circulation